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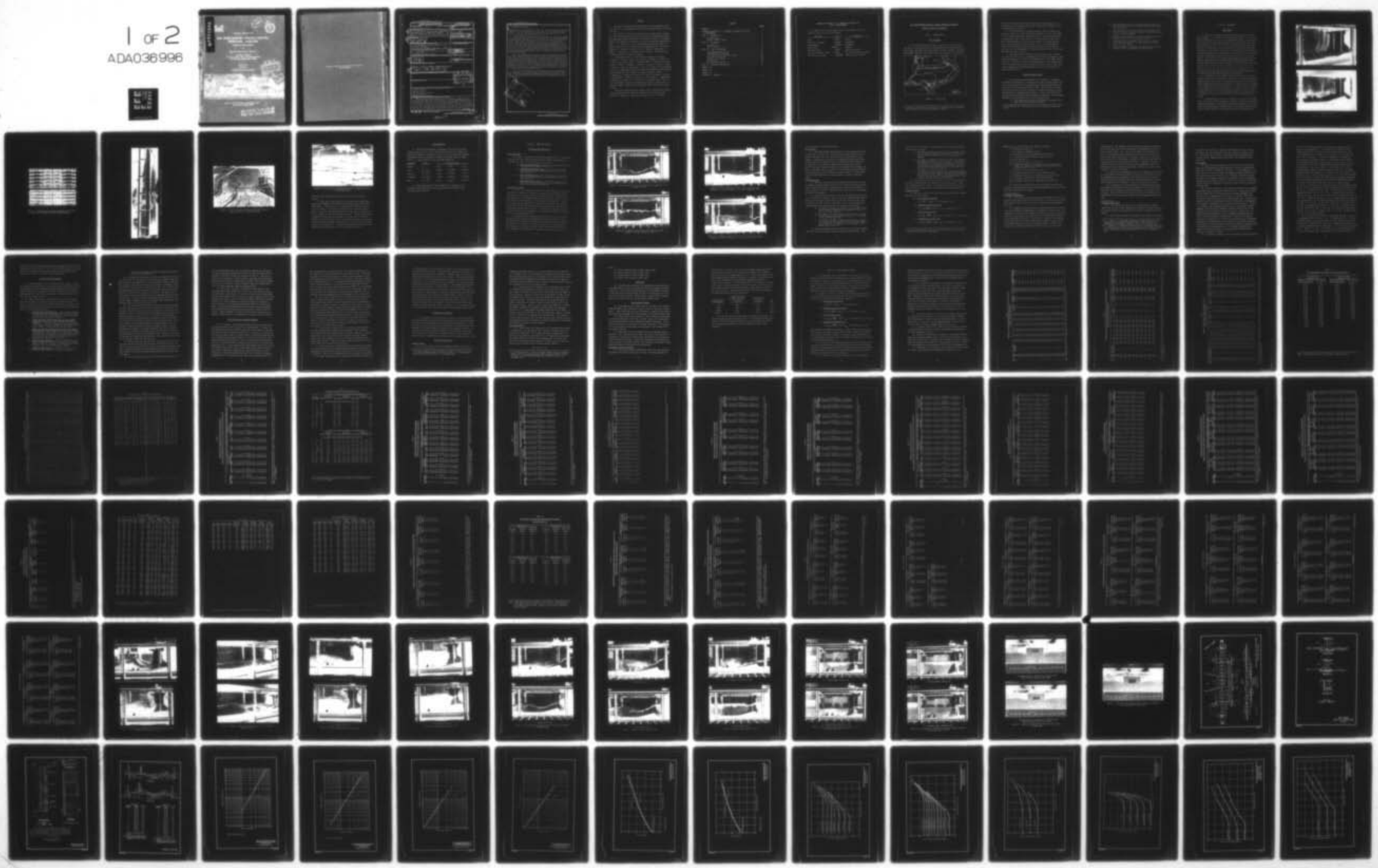

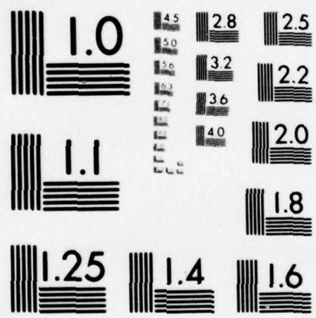

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TECHNICAL REPORT H-77-2

OLD RIVER EXISTING LOW-SILL CONTROL STRUCTURE, LOUISIANA

Hydraulic Model Investigation

by

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Old River Existing Low-Sill Control Structure consists of eleven 44-ft-wide gate bays, Nos. 1-11 from right to left looking downstream, separated by piers. The three center bays (low gate bays) have a crest elevation of -5.0 ft; and the eight outer bays (high gate bays), four bays on each side of the center section, have a crest elevation of +10.0 ft. The stilling basin consists of a horizontal apron, divided into three sections, that is surmounted with two rows of staggered 10-ft-high baffles spaced 12 ft apart and

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20. ABSTRACT (Continued).

terminated with a 3-ft-high vertical end sill. The center section, located downstream of the low gate bays, is 150 ft wide and has an apron elevation of -12.0 ft. The two outer sections, downstream of the high gate bays, are 221 ft wide and have an apron elevation of -5.0 ft.

Model investigations were conducted using two 1:36-scale section models and a 1:150-scale section model to evaluate and develop a satisfactory means of regulating the existing structure to achieve the desired flow objectives without creating adverse hydraulic flow conditions. The model was also used to study the stilling basin performance and flow characteristics for uncontrolled- and controlled-flow operations, measure the dynamic loads induced in the cables and supporting devices during placement of the vertical-lift gates, pressures along the structure (weir crest to stilling basin apron) and velocities in the approach, stilling basin, and exit channel and to determine by observation the relative degree of turbulence in the stilling basin and exit channel.

Model tests indicated that partial closure of the gate bays from the top of the structure (orifice flow under the gates) would be the most effective method of regulating the structure and maintaining satisfactory stilling basin performance and is therefore the recommended plan of regulating the existing structure. The Froude number of flow in the exit channel should not exceed 0.5 for any gate opening downstream of the low bays and 0.4 for gate openings below 11.25 ft and 0.5 for gate openings greater than 11.25 ft downstream of the high bays. Pressures obtained for a range of flow conditions indicated no serious negative pressures should be encountered on boundaries of the prototype structure subject to flow.

The model also indicated that with one gate bay fully closed and adjacent bays open severe turbulence was induced upstream of the fully closed gate. Therefore, the method of regulating the structure by means of fully closing various gate bays should be discontinued for headwaters in excess of 37.0 ft msl.

PREFACE

The model investigation reported herein was requested and authorized by the U. S. Army Engineer District, New Orleans (NOD), on 17 January 1975.

The study was conducted during the period January 1975 to December 1975 in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, and under the general supervision of Messrs. J. L. Grace, Jr., Chief of the Structures Division, and J. P. Bohan, former Chief of the Spillways and Channels Branch. The project engineer for the model study was Mr. E. D. Rothwell, assisted by Messrs. P. Saunders, S. T. Maynord, and B. Perkins. This report was prepared by Messrs. Rothwell and Grace.

During the course of the investigation, Messrs. H. Willis, B. Howell, J. Ryan, S. Powell, W. McIntosh, E. Dodson, H. Pointon, and C. Guam of the Office, Chief of Engineers; MG F. P. Koisch, COL John L. Cannon, R. Resta, R. Kaufman, C. Trahan, F. Weaver, R. Louque, L. Cook, E. Walker, H. Reed, R. Armstrong, J. Harz III, I. Behr, and R. Dubuisson of the U. S. Army Engineer Division, Lower Mississippi River/Mississippi River Commission; and J. Baehr, F. Chatry, B. Kemp, R. Hardy, P. Napolatino, E. Barton, B. Fairless, J. Roy, R. Kliebert, W. Sommer, R. Brupbacher, W. Judlin, T. Johnson, Jr., B. Bleicher, C. Guggenheimer, G. Jesclard, A. Becnel, Jr., I. Moss, Jr., J. Martin, and G. Pilie of NOD visited WES to discuss the program and results of model tests, observe the model in operation, and correlate these results with design studies.

Directors of WES during the conduct of the study and the preparation and publication of this report were COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
pounds (mass)	0.4535924	kilograms
kips (force)	4448.222	newtons
feet per second	0.3048	metres per second
feet per second per second	0.3048	metres per second per second
cubic feet per second	0.02831685	cubic metres per second

OLD RIVER EXISTING LOW-SILL CONTROL STRUCTURE, LOUISIANA

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. The Old River Low-Sill Control Structure is located on the west bank of the Mississippi River approximately 50 miles* northwest of Baton Rouge, Louisiana, and approximately 35 miles southwest of Natchez, Mississippi (Figure 1). The control structure consists of a reinforced

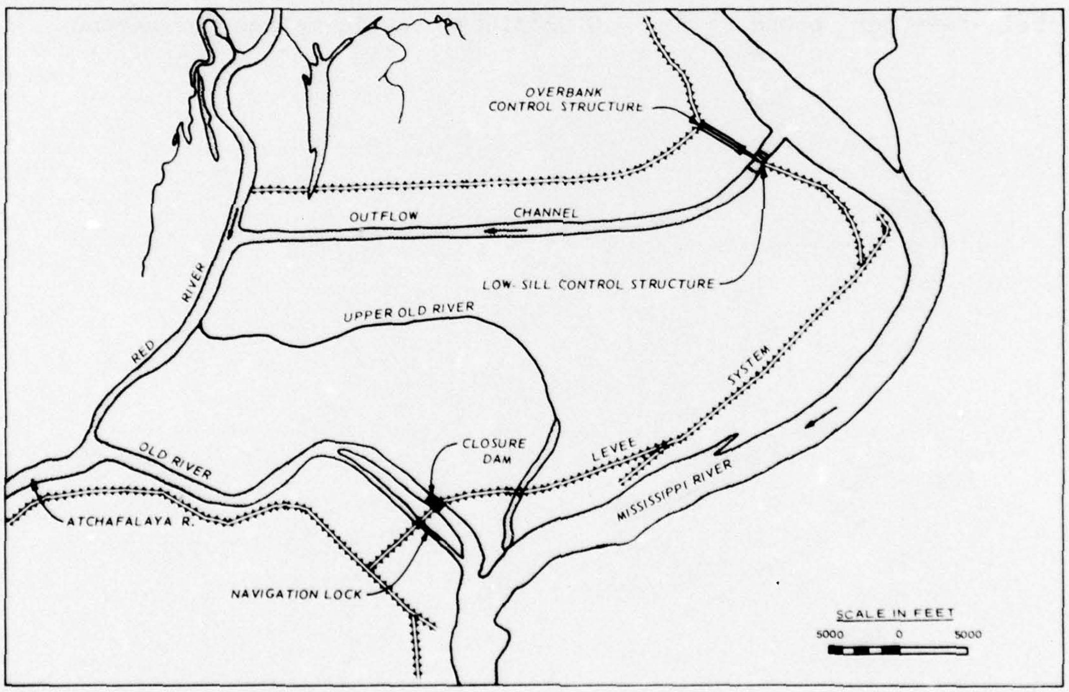

Figure 1. Vicinity map

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

concrete structure with vertical-lift gates and stilling basin, an inflow channel from the Mississippi River, and an outflow channel to the Atchafalaya River and Basin.

2. The structure has a spillway length of 566 ft between abutments and consists of eleven 44-ft-wide gate bays, Nos. 1-11 from right to left looking downstream, separated by piers. The three center bays (low gate bays) have a crest elevation of -5.0*; and the eight outer bays (high gate bays), four bays on each side of the center section, have a crest elevation of +10.0 (Plates 1 and 2). The gate bays are fitted with multileaf, vertical-lift gates operated by an overhead gantry crane. The arrangement of these gate leaves for the low and high gate bays is shown in Plate 3.

3. The stilling basin consists of a horizontal apron, divided into three sections, that is surmounted with two rows of staggered 10-ft-high baffles spaced 12 ft apart and terminated with a 3-ft-high vertical end sill. The center section, located downstream of the low gate bays, is 150 ft wide and has an apron elevation of -12.0. The two outer sections, downstream of the high gate bays, are 221 ft wide and have an apron elevation of -5.0.

Purpose of Model Study

4. The spillway sectional models were conducted to investigate the hydraulic performance to be expected with the existing low-sill control structure under both the immediate and long-range operating conditions for controlled and uncontrolled flows. Specifically, the model study would provide the data necessary to evaluate and develop a satisfactory means of regulating the structure to achieve the desired flow objectives without creating adverse hydraulic conditions. The following information was obtained for the low and high gate bays:

  a. Flow characteristics and stilling basin performance with gates fully open (uncontrolled flow).

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* All elevations (el) cited herein are in feet referred to mean sea level.

b. Flow characteristics and stilling basin performance with one and two gate leaves installed on the weir crest (weir flow over gates).

c. Flow characteristics and stilling basin performance with partial closure of the gates from the top of the structure (orifice flow under gates).

d. Dynamic loads induced in the cables and supporting devices during placement of the vertical-lift gates.

e. Pressures along the structure (weir crest to stilling basin apron) and velocities in the approach, stilling basin, and exit channel.

f. Relative degree of turbulence (as shown by dye) observed visually in the stilling basin and exit channel.

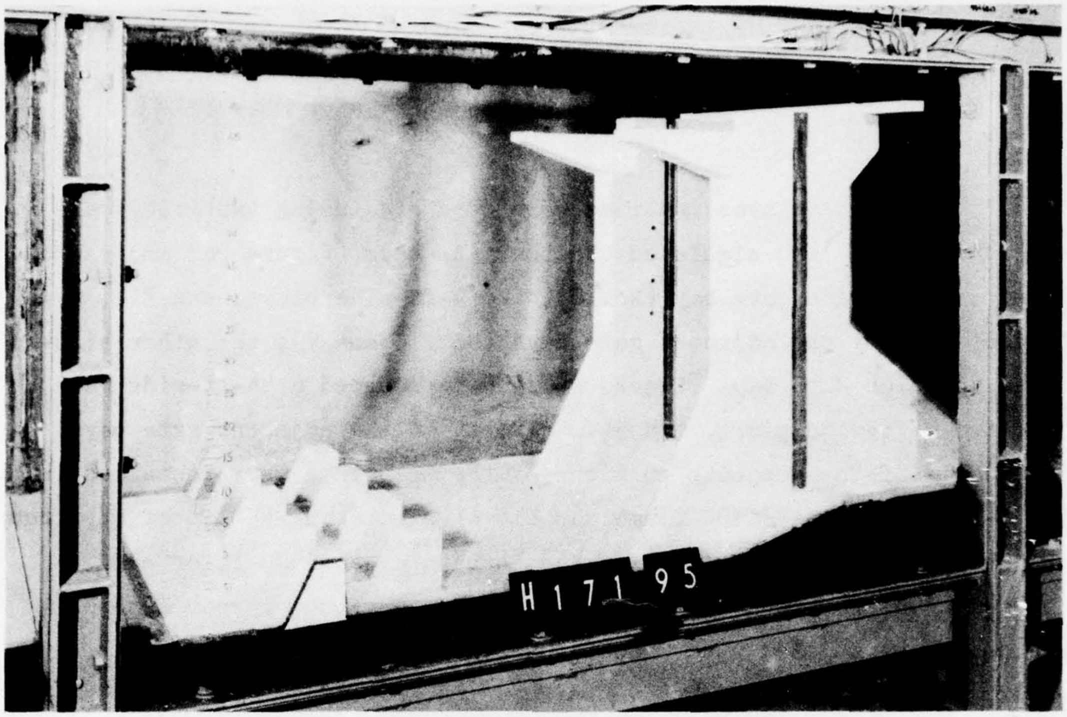
PART II: THE MODELS

Description

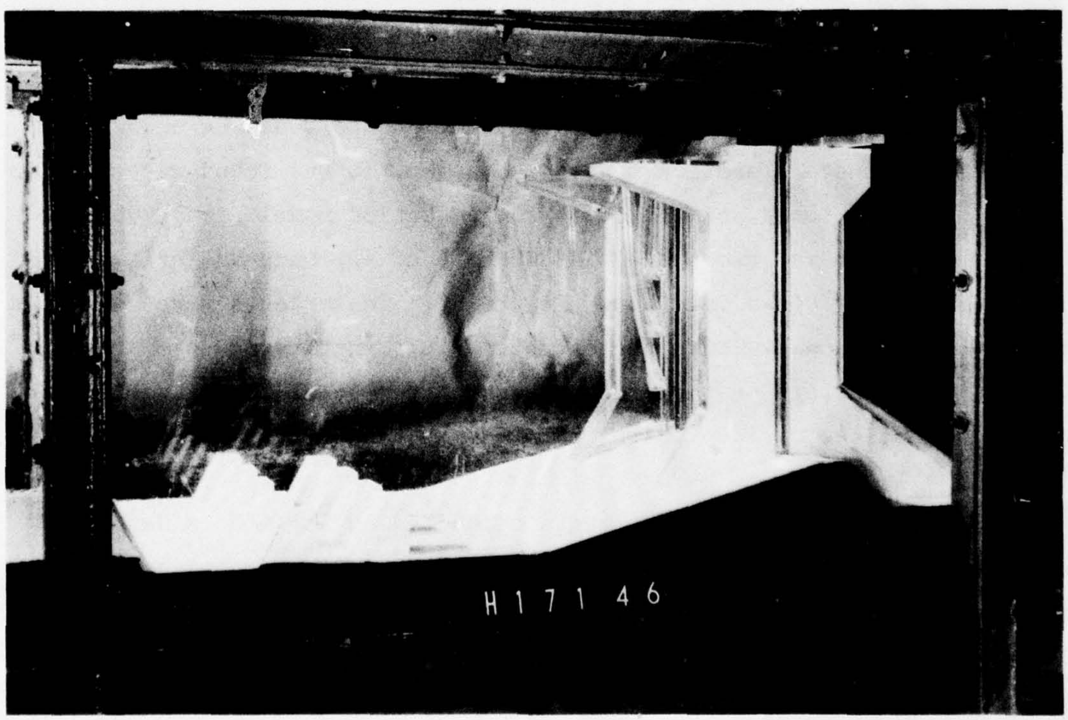
5. Separate investigations were conducted using two 1:36-scale section models: one simulated the low gate bays (Figure 2a) and reproduced a 44-ft-wide gate bay (No. 6), two 9-ft-wide piers, and 31.8 percent of each of the adjacent gate bays (Nos. 5 and 7); the other simulated the high gate bays (Figure 2b) and reproduced a 44-ft-wide gate bay, two 8-ft-wide piers, and 34.0 percent of the adjacent gate bays. The models of the separate portions of the structure were installed in a 2.5-ft-wide glass-sided flume capable of simulating 650 ft of approach channel, a 90-ft-wide section of the structure, and 500 ft of exit channel. The portions of the model representing the approach and exit channels were modeled with plastic-coated plywood and treated with a waterproofing compound to prevent expansion. The weir crests and stilling basin aprons were fabricated of sheet metal. The crest piers, baffle blocks, and end sills were fabricated of transparent plastic. The vertical-lift gate leaves were of plate girder construction with a skin plate on the upstream side (Figure 3 and Plate 3).

6. Initially, it was planned that all tests would be conducted using the 1:36-scale section models. However, it was found necessary to conduct certain tests using a 1:150-scale section model simulating the three low gate bays, two piers, and 2000 ft of approach and exit channel in a 1-ft-wide glass-sided flume (Figure 4). These tests were conducted to investigate and evaluate the effects of alternative modes of regulating the structure on the existing downstream scour configuration and to supplement the various tests conducted in the 1:36-scale section models.

7. Supplementary to the tests conducted in the models described above, observation of flow patterns, velocities, discharges, and overall hydraulic performance of the low-sill structure was made in the 1:120-scale (three-dimensional) fixed-bed model. This model reproduced the entire low-sill (Figure 5) and overbank (Figure 6) structures with



a. Low gate bays



b. High gate bays

Figure 2. 1:36-scale section models

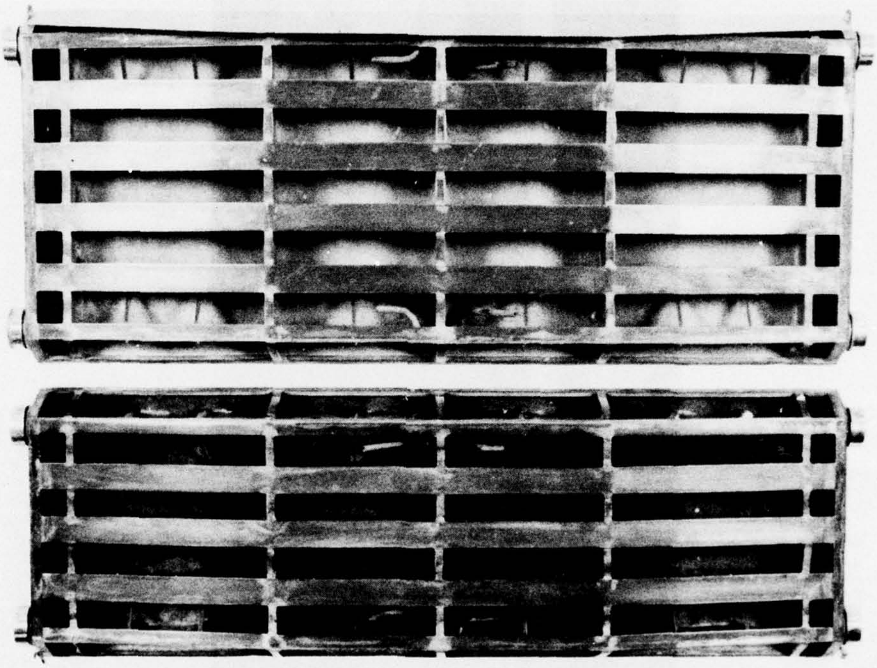


Figure 3. Downstream side of gate leaves 3L (19 ft high) and 4L (15 ft high) showing structural details

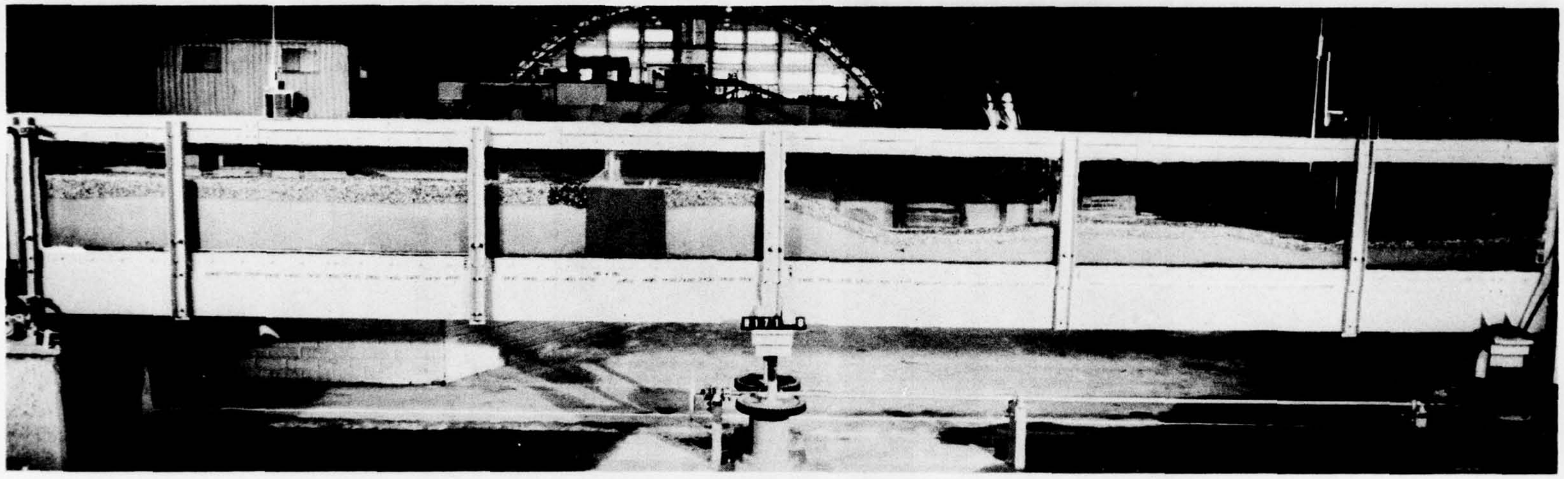


Figure 4. 1:150-scale section model of low gate bays

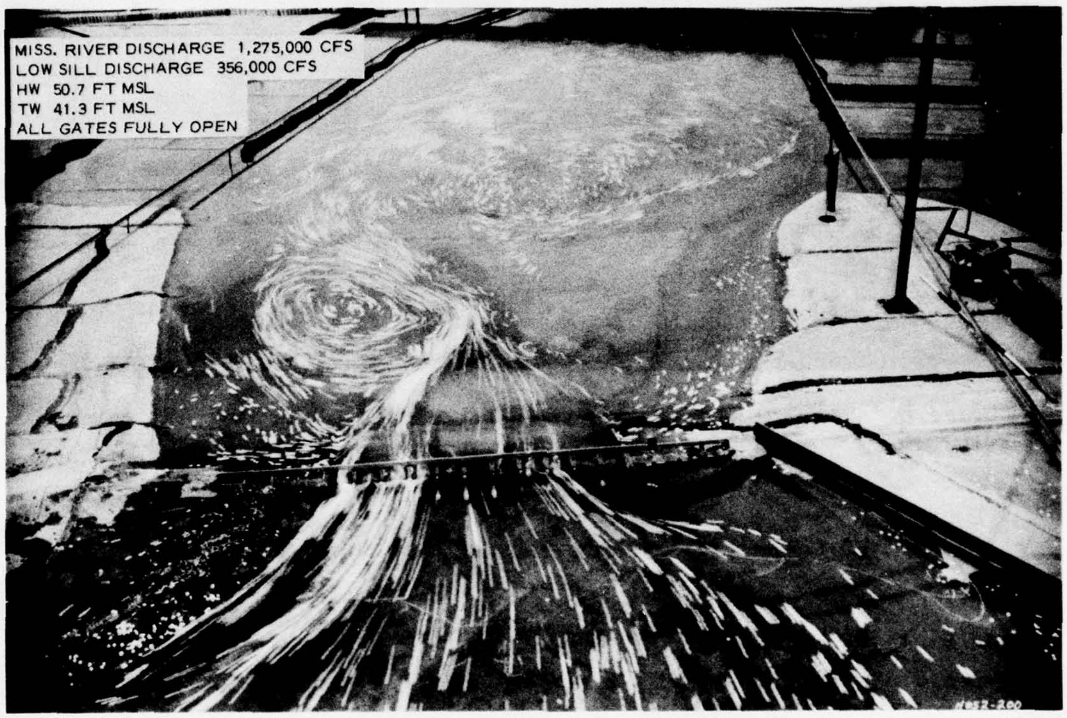


Figure 5. The 1:120-scale comprehensive model low-sill control structure, looking downstream

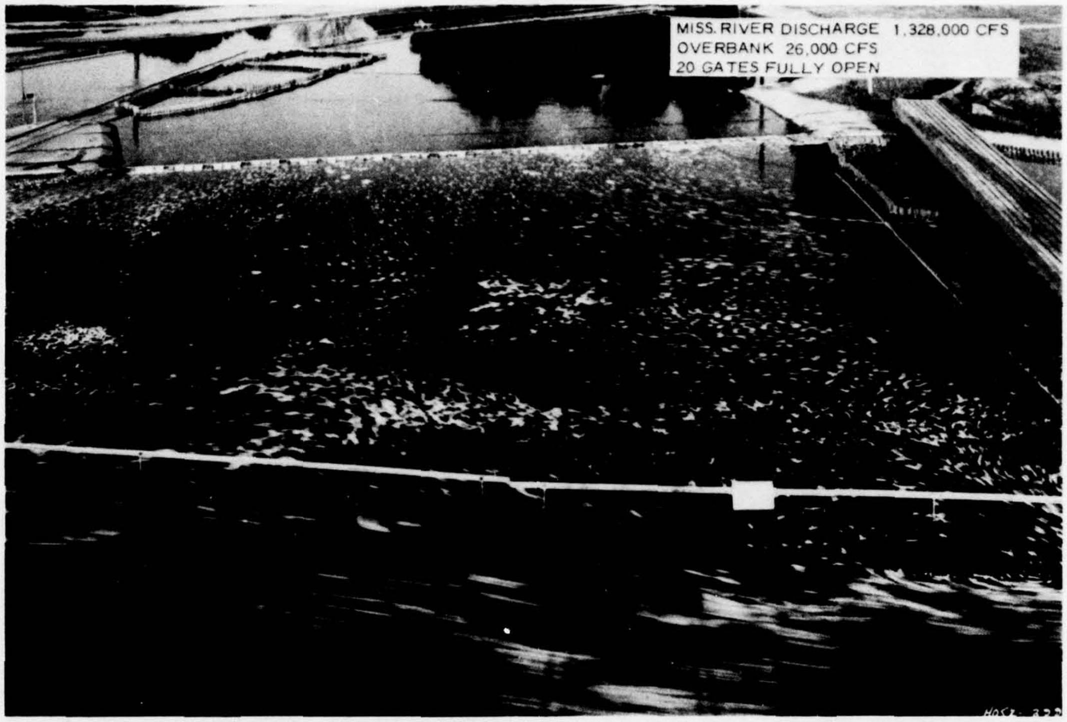


Figure 6. The 1:120-scale comprehensive model overbank structure, looking downstream

portions of the connecting levees and the approach and outflow channels.

8. Water used in the operation of the models was supplied by pumps, and discharges were measured by means of venturi and orifice plate meters. Steel rails set to grade provided reference planes for measuring devices. Water-surface elevations were obtained by point gages. Velocities were measured with pitot tubes and by stopwatch timing of movement of dye over a measured distance. Current patterns were determined by observing the movement of dye injected into the water. Dynamic loads were measured by load cells which monitored the instantaneous and continuous dynamic loads exerted on the vertical gate leaves during their installation. Pressures were measured by piezometer tubes installed along the center line of the structure (Plate 4).

Scale Relations

9. The accepted equations of hydraulic similitude, based upon Froudian criteria, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and prototype. The general relations expressed in terms of the model scale or length ratio, L_r, are presented in the following tabulation:

Dimension	Ratio	Scale Relations		
Length	L_r	1:36	1:120	1:150
Area	$A_r = L_r^2$	1:1296	1:14,400	1:22,500
Velocity	$V_r = L_r^{1/2}$	1:6.0	1:10.95	1:12.24
Discharge	$Q_r = L_r^{5/2}$	1:7776	1:157,744	1:275,567
Time	$T_r = L_r^{1/2}$	1:6.0	1:10.95	1:12.24

10. Model measurements of each dimension or variable can be transferred quantitatively to prototype equivalents by means of the preceding scale relations.

PART III: TESTS AND RESULTS

Discharge Characteristics

Flow conditions

11. Tests to determine the discharge characteristics of the spillway structure with various approach and exit channel elevations were conducted for each of the following flow conditions:

- a. Free uncontrolled flow: gates fully open; upper pool unaffected by the tailwater (Figure 7).
- b. Submerged uncontrolled flow: gates fully open; upper pool controlled by the submergence effect of the tailwater (Figure 8).
- c. Free controlled flow: gates partially open; upper pool controlled by gate opening and unaffected by the tailwater (Figure 9).
- d. Submerged controlled flow: gates partially open; upper pool controlled by gate opening and the submergence effect of the tailwater (Figure 10).

Description of tests

12. Tests to determine the discharge characteristics of the structure for free uncontrolled flows were conducted by introducing various discharges into the model, with the tailwater below the spillway crest, and observing the corresponding upper pool elevations. Sufficient time was allowed for stabilization of the upstream flow conditions. Upper pool elevations were measured at a point 400 ft upstream from the axis of the weir, and tailwater elevations were measured at a point 325 ft downstream from the axis of the weir. A similar procedure was followed for various partial gate operations to determine the discharge characteristics of free controlled flow.

13. Submerged-flow discharge characteristics for both controlled and uncontrolled flows were determined by introducing several constant discharges into the model and varying the tailwater by small increments for each from an elevation at which no interference in spillway flow was evident to an elevation at which the flow was practically 100 percent submerged. The elevation of the upper pool was noted at each

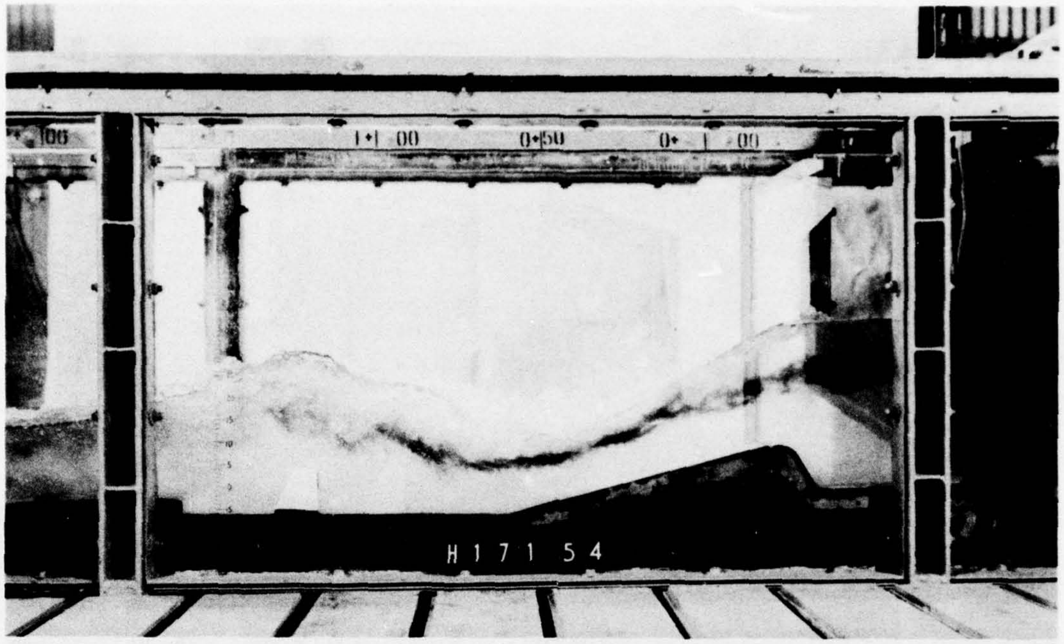


Figure 7. Free uncontrolled flow, high gate bays; headwater el 40.0, tailwater el 10.8

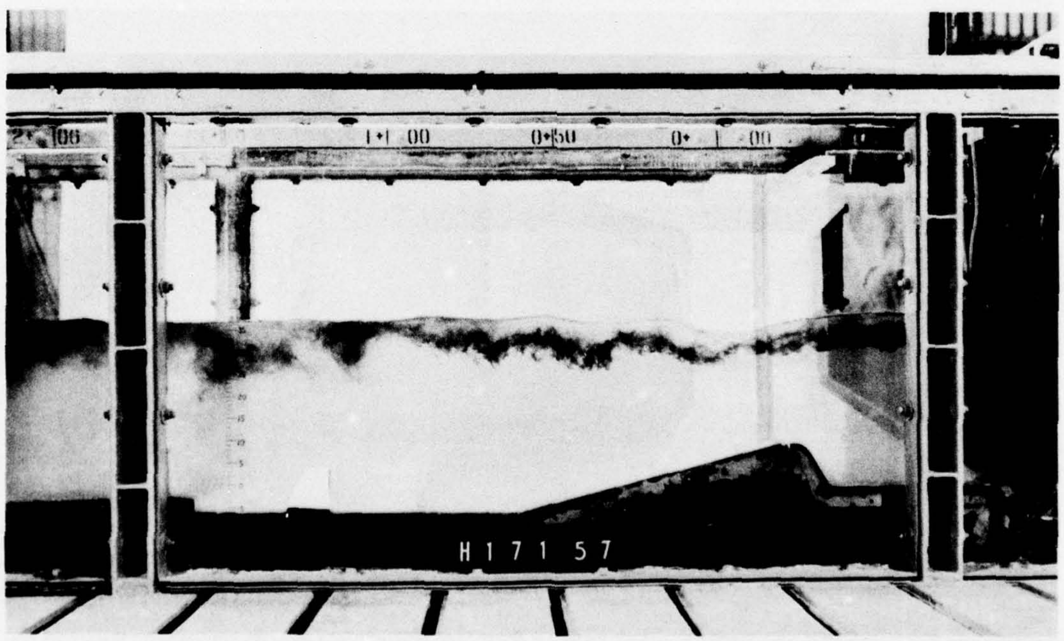


Figure 8. Submerged uncontrolled flow, high gate bays; headwater el 40.0, tailwater el 39.2

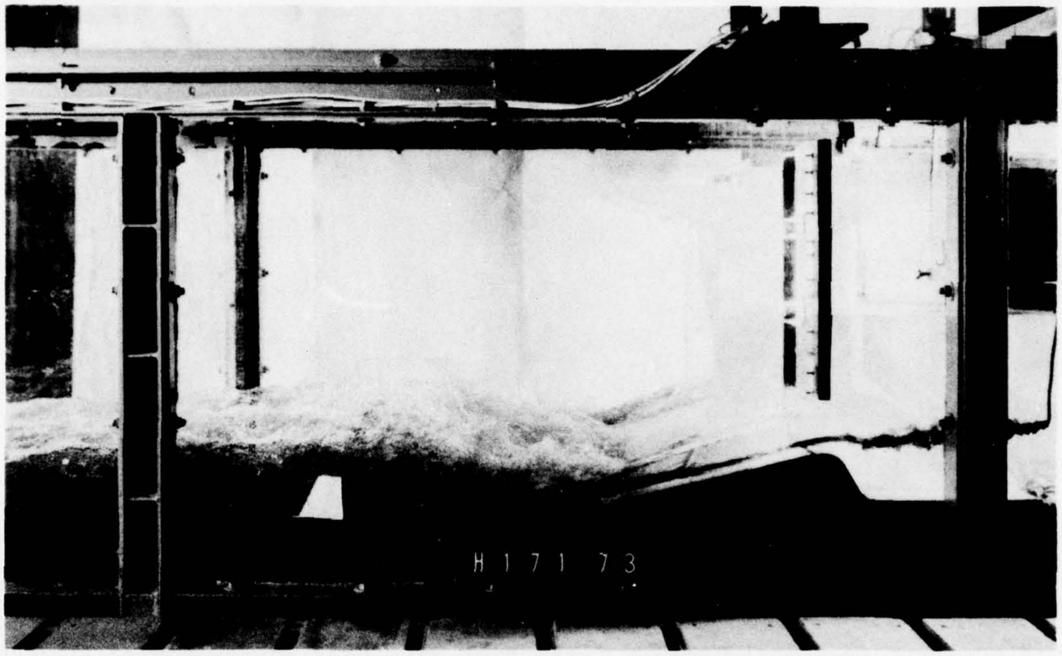


Figure 9. Free controlled (orifice) flow, high gate bays; headwater el 40.0, tailwater el 5.0, gate opening 11.25 ft

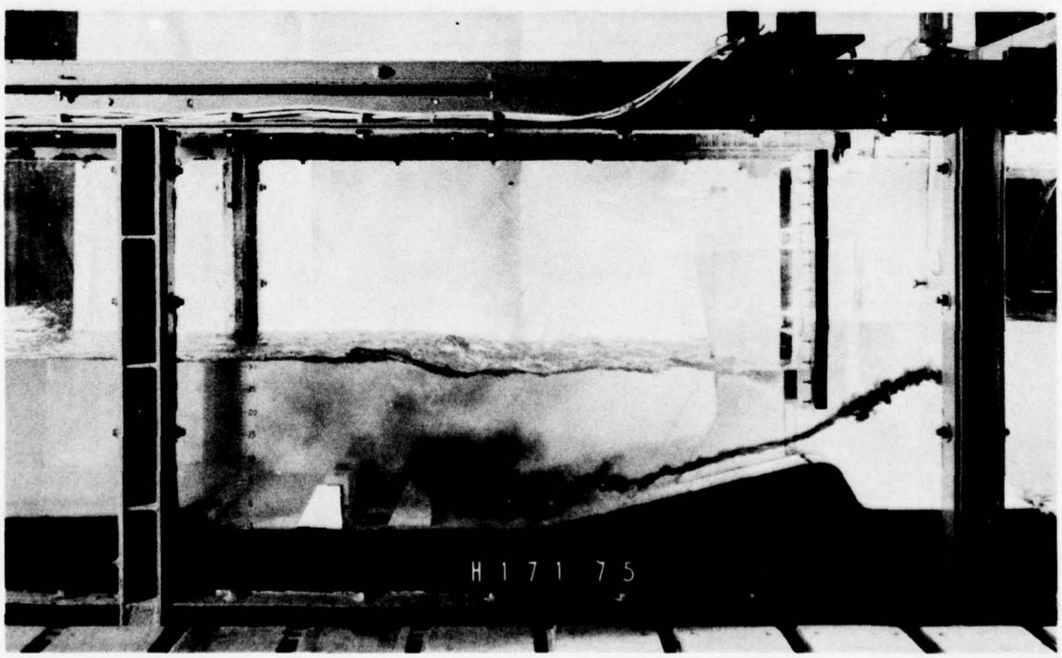


Figure 10. Submerged controlled (orifice) flow, high gate bays; headwater el 40.0, tailwater el 33.0, gate opening 11.25 ft

of the respective tailwater elevations.

Weir capacity

14. The head-discharge rating curves for free uncontrolled flow are presented in Plates 5-8. The equation for each of these curves is the best empirical fit of the free flow data by the method of least squares. Comparisons of the model and computed spillway rating curves for both the low and high gate bays are presented in Plates 9 and 10. The capacity of the structure indicated by the model was slightly greater than that computed in 1966 by the Mississippi River Commission. This is reasonable and is attributed to the difference between approach flow conditions in the two-dimensional section model of constant width and the three-dimensional prototype approach of variable width and depth.

Calibration data

15. The basic calibration data, presented in Plates 11-27, show the approach channel energy elevation (water surface plus velocity head based on average velocity) corresponding to a particular elevation of the tailwater for a given discharge observed with both the low and high gate bay section models.

16. Uncontrolled-flow data for the low and high gate bay portions of the structure are shown in Plates 11 and 12. Uncontrolled-flow data with one and two gate leaves resting on the sill of the low gate bays are shown in Plates 13 and 14. The data for each of the various discharges shown in the respective plates illustrate the following:

- a. The relation between the elevation of the energy of flow in the approach channel and the elevation of the tailwater in the exit channel.
- b. The range of tailwater elevations at which the elevation of the approach flow energy is constant, i.e. the range of free uncontrolled flow.
- c. The range of tailwater elevations at which the elevation of the approach flow energy is controlled by the submergence effect of the tailwater, i.e. the range of submerged uncontrolled flow.

17. Free and submerged controlled-flow data for the low and high gate bays with various gate openings are shown in Plates 15-27. The

data for each of the various discharges shown in the respective plates illustrate the following:

<u>a</u>. The relation between the elevation of the energy of flow in the approach channel and the elevation of the tailwater in the exit channel for the particular gate opening.

<u>b</u>. The range of tailwater elevations at which the energy of the approach channel flow is constant, i.e. the range at which the flow is free from the submergence effects of the tailwater, and either free uncontrolled or free controlled flow exists depending upon the discharge, gate opening, and total head on the weir.

<u>c</u>. The range of tailwater elevations at which the elevation of the approach flow energy is controlled by the submergence effect of the tailwater, and the range at which the flow is controlled by both the submergence effect of the tailwater and the particular gate opening.

18. Discharge-head relations and data for free flow conditions in the low and high gate bays are presented in Plates 28 and 29. These plots represent partial closure of the gates from the top of the structure (orifice flow under gates) for both the low and high gate bays.

<u>Analyses of data</u>

19. The flow conditions and equations used to satisfy the experimental data are as follows:

<u>a</u>. <u>Free uncontrolled flow:</u>

$Q = CLH^{3/2}$, where C is a function of H*

<u>b</u>. <u>Submerged uncontrolled flow:</u>

$Q = C_s Lh \sqrt{2g\Delta H}$, where C_s is a function of h/H

<u>c</u>. <u>Free controlled flow:</u>

$Q = C_g LG_o \sqrt{2gH_g}$, where C_g is a function of H_g and G_o

<u>d</u>. <u>Submerged controlled flow:</u>

$Q = C_{g_s} Lh \sqrt{2g\Delta H}$, where C_{g_s} is a function of h/G_o

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* For convenience, symbols and unusual abbreviations are listed and defined in the Notation (Appendix A).

Symbols used in these equations are defined as follows:

Q = discharge per bay, cfs

L = net length of spillway crest, ft

H = total head on weir (including velocity head), ft

h = tailwater elevation referred to weir crest, ft

G_o = gate opening, ft

H_g = total head on gate $(H - G_o/2)$, ft

ΔH = difference between total energy of flow in the approach channel and elevation of tailwater with reference to the spillway crest $(H - h)$, ft

g = acceleration due to gravity, ft/sec^2

C = discharge coefficient for free uncontrolled flow

C_s = discharge coefficient for submerged uncontrolled flow

C_g = discharge coefficient for free controlled flow

C_{g_s} = discharge coefficient for submerged controlled flow

20. Quantities determined from the experimental data were substituted in the equations, and the discharge coefficients for the respective flow conditions were computed.

Uncontrolled-flow
discharge coefficients

21. Free uncontrolled-flow discharge coefficients for the low and high gate bays are presented in Plates 30 and 31. Similar data with two gate leaves resting on the sill of the low gate bays are presented in Plate 32.

22. Submerged uncontrolled-flow discharge coefficients resulting from various degrees of submergence are presented in Plates 33-35. The submerged uncontrolled-flow discharge coefficients for the low gate bays indicate an increase in the coefficient with a corresponding increase in the submergence (Plate 33). This trend is similar to the submerged uncontrolled flow over a broad-crested weir in which the nappe flows horizontally between the crest and tailwater surface. Similar test results with a broad-crested weir were obtained in a previous model

investigation.* The submerged uncontrolled-flow discharge coefficients for the high gate bays varied considerably for submergences of 85 percent or greater (Plate 34). This variation may be contributed to the fact that the degree to which model scale effects vitiate calibration data at small head differentials is unknown. However, it is suspected that viscous effects predominate with small head differentials and yield increased values of the discharge coefficient. Therefore, the high values of the coefficient obtained with deep submergences (small head differentials) are considered questionable. Similar test results were obtained in a previous model.**

23. However, the recommended trends of the submerged uncontrolled-flow discharge coefficients presented in Plates 33 and 34 were verified by comparing measured experimental data obtained from the 1:120-scale fixed-bed model with computed quantities determined from the 1:36-scale section models and data analyses. Results are presented in Table 1.

24. An analysis of the data was made to distinguish between free and submerged uncontrolled flow and to determine the relations between swellhead, unit discharge, and tailwater relative to the crest of the spillway. Results of this analysis (Plates 36 and 37) indicate that a transitional flow regime exists between free and submerged uncontrolled flow.

Controlled-flow discharge coefficients

25. The relations between the free controlled-flow discharge coefficient and various gate openings are presented in Plates 38 and 39. An alternate method of presenting free flow data is shown in Plates 28 and 29.

26. The relations between the submerged controlled-flow discharge

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* J. L. Grace, Jr., "Spillway for Typical Low-Head Navigation Dam, Arkansas River, Arkansas," Technical Report 2-655, Sep 1964, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

** J. L. Grace, Jr., "Typical Spillway Structure for Central and Southern Florida Water-Control Project," Technical Report 2-633, Sep 1963, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

coefficient and the ratio of tailwater depth above the crest to gate opening for the low and high gate bays are presented in Plates 40 and 41. These model data indicate a reasonable trend for submerged controlled flows as compared with previous model investigations (Plates 42 and 43).

Flow regimes

27. Model data were analyzed to define the limits of each flow regime and corresponding discharge equation in terms of dimensionless quantities in order to generalize the results. An investigation of the basic data curves, with a constant discharge and either uncontrolled or controlled flow, reveals that there is a tailwater elevation at which the energy of the approach channel flow increases with a corresponding increase in the tailwater elevation. This is the elevation at which the tailwater begins to submerge or control the flow, and free flow becomes submerged flow.

28. Results of analyses to distinguish between free and submerged uncontrolled flows are shown in Plates 44 and 45. These plates in general illustrate that free uncontrolled flow becomes submerged uncontrolled flow for submergences (h/H) equal to or greater than 72 and 60 percent, respectively, for the low and high gate bays. Similar plots indicate that free and submerged controlled flows can be distinguished by the degree of submergence as indicated in Plates 46 and 47. Results of other model data analyses that may be used to distinguish between submerged uncontrolled and submerged controlled flows in the low and high gate bays are presented in Plates 48 and 49, respectively. Although the data represented in these submerged-flow regimes were obtained from previous model investigations of similar but different spillway weir geometries, the results were analyzed and the recommended application is substantiated since comparisons of predicted total discharge based on the section model and previous model data analyses agree reasonably with those measured in the 1:120-scale fixed-bed model. Results for both uncontrolled- and controlled-flow conditions are presented in Tables 1, 2, and 3.

29. To define the limits of free controlled and free uncontrolled

flows for the low and high gate bays, results of previous tests and analyses are recommended. It is considered that controlled flow becomes uncontrolled flow when the ratio of total head on the weir to gate opening (H/G_o) is equal to or less than 1.5 for the low bays and 2.0 for the high bays. Relations recommended to distinguish the submerged flow regimes through the low gate bays with tailwater depth-to-gate opening (h/G_o) ratios equal to or less than 1.0 to 1.2 are presented in Plate 48. Submerged-flow regimes through the high gate bays with h/G_o ratios equal to or less than 1.0 to 1.3 may be distinguished based on results presented in Plate 49. In distinguishing between flow regimes, it is noted that for conditions of h/G_o less than 1.0 to 1.2 with low gate bays and 1.0 to 1.3 in the high gate bays, the flow may be either free uncontrolled, submerged uncontrolled, or free controlled, depending upon the ratio of differential between total head and tailwater depth above the crest to gate opening $(H - h)/G_o$ and the ratio of total head on the crest to the gate opening (H/G_o). For the low gate bays, Plate 48 indicates that if the ratio of $(H - h)/G_o$ is less than 0.2 and H/G_o is less than 1.5, the flow is submerged uncontrolled. If $(H - h)/G_o$ is greater than 0.2 but less than 0.5 and H/G_o is less than 1.5, the flow is free uncontrolled. If $(H - h)/G_o$ is greater than 0.5 and H/G_o is greater than 1.5, the flow is free controlled. For the high gate bays, Plate 49 indicates that if the ratio of $(H - h)/G_o$ is less than 0.5 and H/G_o is less than 2.0, the flow is submerged uncontrolled. If $(H - h)/G_o$ is greater than 0.5 but less than 1.0 and H/G_o is less than 2.0, the flow is free uncontrolled. If $(H - h)/G_o$ is greater than 1.0 and H/G_o is greater than 2.0, the flow is free controlled.

30. In using these criteria for determining the type of flow, it is recommended that the value of H/G_o be determined first. If H/G_o is greater than 1.5 for low gate bays or 2.0 for high gate bays, controlled flow is indicated and either free or submerged controlled flow is possible depending upon the submergence, h/H, as shown in Plates 46 and 47. However, if H/G_o is less than 1.5 for the low gate bays or 2.0 for the high gate bays, uncontrolled flow is indicated and it is

possible that the flow may be either free or submerged uncontrolled flow depending upon the values of H and h/H (Plates 44 and 45), and there is also a possibility of submerged controlled flow depending on the values of $(H - h)/G_o$ and h/G_o (Plates 48 and 49).

Stilling Basin Performance

31. Flow performance of the existing structure (Plates 1 and 2) was obtained with uncontrolled- and controlled-flow operations for both the existing and future headwater/tailwater conditions. For each of these conditions the stilling basin action was observed and velocities were measured at a point 100 ft downstream of the end sill and 10 ft above the exit channel bottom.

32. Model observations indicated that five types of stilling basin action might occur within the range of tailwater elevations at which the existing low-sill structure may be required to operate. The types of action observed in the 1:36-scale section models are shown in Photos 1-5 and are described below:

- a. Supercritical spray (Photo 1). The jet sweeps through the stilling basin and impinges upon the baffle blocks and end sill; and supercritical flow exists throughout the stilling basin and exit channel.
- b. Forced jump with supercritical flow in exit channel (Photo 2). Tailwater is less than that required for formation of a hydraulic jump; however, the resistance to flow due to the basin elements is sufficient to maintain a hydraulic jump within the stilling basin.
- c. Hydraulic jump with standing waves in the exit channel (Photo 3). The basin elements are sufficient to maintain a hydraulic jump within the stilling basin; however, standing waves are generated in the exit channel due to the relatively low tailwater and acceleration of flow immediately downstream of the end sill.
- d. Hydraulic jump (Photo 4). The jet is broken up by the basin elements and tailwater is sufficient to maintain hydraulic jump action within the stilling basin and subcritical flow in the downstream exit channel.
- e. Submerged jump (Photo 5). Tailwater elevation is in excess of that required for a hydraulic jump and

sufficient to submerge the nappe flowing under the gate and the downstream gate lip.

33. Stilling basin performance for free and submerged uncontrolled flow through the low and high gate bays (gate leaves removed, gate bays fully open) was investigated for various headwater/tailwater conditions. Stilling basin performance below the low gate bays for headwater elevations of 30.0, 40.0, and 52.0 is presented in Plate 50. Stilling basin performance below the high gate bays for headwater elevations of 30.0, 40.0, 45.0, and 55.0 ft is presented in Plate 51. The same types of stilling basin action were observed with the high gate bays as with the low gate bays. Actions termed forced jump with supercritical flow in the exit channel, hydraulic jump, and submerged jump downstream of the high gate bays are illustrated in Photos 6-8.

34. Stilling basin performance for operations involving one gate leaf (4L) and two gate leaves (4L and 3L) installed on the crest of the low bays to create a weir with a crest elevation of 10.0 and 29.0, respectively, were also obtained for various headwater and tailwater conditions as shown in Plates 52 and 53. The types of stilling basin action associated with various flow conditions over weir elevations of 10.0 and 29.0 are illustrated in Photos 9 and 10, respectively. These plots indicate that the basin would perform satisfactorily with the tailwater elevations expected during low headwater stages. However, performance with greater than normal headwaters and lesser tailwaters indicated an uncertainty in controlling the distribution of flow from the Mississippi River down the Atchafalaya River. Therefore, evaluation of this method of regulating the structure, with uncontrolled flow over one or more gate leaves, was discontinued.

35. Results obtained from tests with the low gate bay portion of the structure indicate that controlled-flow conditions resulting from partial closure of the gates from the top of the structure (orifice flow under the gates) would be the most appropriate method for regulating flow through the structure and maintaining satisfactory stilling basin performance.

36. The conditions under which the existing stilling basins for

the low and high gate bays will be required to operate for controlled flow were established by assuming that the vertical-lift gates will be operated in various increments as indicated in Table 4. The types of basin action occurring on rising tailwater, beginning with the minimum possible in the model, were supercritical spray, forced jump with supercritical flow in the exit channel, hydraulic jump with standing waves in exit channel, hydraulic jump, and submerged jump.

37. Tests were conducted to determine the performance of the stilling basins, apron elevations at -12.0 and -5.0, below the low and high gate bays, respectively, for orifice or controlled-flow operations. The relations between velocity in the exit channel (measured 100 ft downstream of the end sill and 10 ft above the channel bottom) and tailwater elevation for various headwaters and gate openings are presented in Plates 54-59 for the low gate bays and Plates 60-66 for the high gate bays. The symbols representing data points indicate the gate opening and tailwater elevation associated with each type of basin action observed. Further analysis of the data indicated that the results presented in Plates 54-66 can be generalized as shown in Plates 67 and 68.

Flow Conditions in the Exit Channel

38. In the past, the existing structure had been operated either with the gate bays in the fully open or closed position. To assist in deciding how the structure should be operated in the future to constrict the flow with either full gate closures, as in the past, or with orifice flow under the gate leaves, a limited number of tests were conducted with the 1:150-scale section model (Figure 4). This model assisted in determining subsurface flow patterns in the exit channel and evaluating the effects of alternative modes of regulating the structure on upstream and downstream scour. Section model tests simulating gate bay 6 fully closed with adjacent bays 5 and 7 open revealed that severe subsurface turbulence with an irregular periodicity was induced upstream of a fully closed gate. The model indicated that this severe turbulence extended approximately 50 ft upstream from the edge of the structure (Photo 11).

This turbulence had a random nature and the conditions under which it was formed can be directly attributed to full gate closure. Any slight adjustment or lifting of the gate to create an opening between the bottom of the gate leaf and the gate sill or spillway crest would eliminate the turbulence (Photo 12). It is expected that this phenomenon contributed to the development of a scour hole which extended approximately 40 ft upstream from the prototype structure (sta 99+48.17) for a maximum width of 165 ft and a depth of 12 ft in front of the low gate bays. It is considered that this method of regulating flow through the low-sill structure should be implemented only with headwaters less than 37.0 ft.

39. Test results obtained in the 1:150-scale section model with partial closure of the gates from the top of the structure (orifice flow) indicate that flows in the stilling basin and exit channel were satisfactory in general, except for operations in the range of stilling basin action termed "hydraulic jump with standing waves in exit channel." This flow condition indicated the local Froude number of flow in the exit channel immediately downstream of the end sill has the potential for initiating scour downstream of the structure. Based on the results of the section model, plans for operating the existing or modified structure should be developed to prevent this type of stilling basin action as well as those termed "forced jump with supercritical flow in exit channel" and "supercritical spray."

40. Tests were not conducted in the 1:150-scale section model with the high gate bays; however, tests conducted in the 1:36-scale section model with the high gate bays did indicate formation of similar undesirable flow conditions in the stilling basin and exit channel. Similar tests were conducted in the 1:120-scale fixed-bed model with various gate closures. These test results support the results obtained in the 1:36- and 1:150-scale section models.

41. These test results indicate that the most appropriate method for controlling flow with and maintaining satisfactory stilling basin performance in the existing low-sill structure is the orifice flow mode of operation. This is the recommended plan for operating the structure.

42. Tests conducted in the 1:36-scale section models with the low

and high gate bays also indicated the formation of a standing wave in the exit channel (Plates 54-66). These data were analyzed to determine the minimum tailwater required to maintain a hydraulic jump in the stilling basin without standing waves in the exit channel. The minimum tailwater curves for the low and high gate bays are presented in Plates 69 and 70, respectively. Flow conditions in the exit channel for the low and high gate bays indicated that the Froude number of flow immediately below the end sill was sufficient to initiate scour. The Froude number of flow was calculated for various flow conditions to distinguish the limits between hydraulic jump, hydraulic jump with standing waves, and forced jump with supercritical flow in the exit channel (Tables 5 and 6). The results were analyzed and indicate that the Froude number of flow in the exit channel downstream of the low gate bays should not exceed 0.5 for any gate opening. The Froude number of flow in the exit channel downstream of the high gate bays should not exceed 0.4 for gate openings equal to or less than 11.25 ft and 0.5 for gate openings greater than 11.25 ft.

Pressures on Structure

43. Piezometers, located as shown in Plate 4, were used to determine the hydrostatic pressures along the center line of the low and high gate bays with both uncontrolled- and controlled-flow conditions. The pressures obtained with various flow conditions are shown in Tables 7-18. Although only a limited number of pressures were measured during the investigation, these data are representative of the range of flow conditions expected at the structure and indicate that no serious negative pressures will be encountered on surfaces of the prototype exposed to flow.

Forces on Gate Leaves

Vertical forces

44. In the original model investigation* emphasis was placed on

* "Old River Low-Sill Control Structure; Downpull Forces on Vertical-Lift Gates," Technical Report 2-447, Dec 1956, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

reproducing two gate leaves in sufficient detail to permit simulation of the dynamic loads to be encountered in placing one or two gate leaves. Two additional gate leaves were fabricated for the subject model tests, and appropriate instrumentation was provided to monitor the instantaneous and continuous dynamic loads or vertical forces encountered during the installation of one to four gate leaves.

45. Initial tests were conducted in the 1:36-scale section model to determine the fluctuation of loads on the cables used to place the gate leaves for partial closure (orifice flow) with a limited number of flow conditions. Results of these tests are presented in Table 19 and no unstable flow conditions or adverse fluctuation of loads was indicated by the model. A decision was made by the sponsoring agency to monitor vibrations and conduct a series of gate loading tests on the prototype structure. Results of these tests are presented in a technical report* prepared by the Hydraulic Analysis Division, Hydraulics Laboratory, U. S. Army Engineer Waterways Experiment Station (WES). In essence, the results obtained in the 1:36-scale model compare favorably with the results of the prototype tests and analysis. The conclusion of these tests indicates that the existing gate leaves, hoisting devices, and dogging devices can be modified to permit regulation of flow through the structure by means of orifice control.

<u>Horizontal forces</u>

46. Limited tests were conducted in the 1:36-scale section model to estimate the total horizontal force induced on the gate leaves for orifice flow operations. Pitot tubes were located approximately 6 ft (prototype) upstream from the front face of the gate leaves to measure the average velocity for various gate openings and flow conditions. The test condition and results tabulated in Tables 20 and 21 were analyzed and are satisfied by the following general equation:

$$F_T = F_1 + F_2 - F_3$$

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* F. M. Neilson and A. R. Tool, "Prototype Tests, Old River Low-Sill Control Structure, April 1973-June 1975," Technical Report H-76-15, Sep 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

where

F_T = total horizontal force acting on gate, kips

F_1 = static force on front of gate, kips

F_2 = velocity head on front of gate, kips

F_3 = static force on back of gate, kips

Velocities

47. Velocities were obtained with uncontrolled- and controlled-flow operations for both the existing and ultimate headwater/tailwater conditions. These velocities were measured 10 ft upstream of the face of the structure at various depths, and 100 ft downstream of the end sill at 10 ft above the exit channel bottom. The velocities obtained with various flow conditions are presented in Tables 22-27.

Miscellaneous Testing

48. Miscellaneous tests, which were not included in the original testing program, were conducted during the course of the model investigation. These additional tests were required to supplement and substantiate prototype findings and provide guidance for solving problem areas.

49. Several tests were conducted in the 1:36-scale section model to determine pressures, velocities, vertical loads, and stilling basin action associated with various headwater/tailwater elevations. These tests were required in order that a stability analysis of the structure for the existing and anticipated flow conditions could be made by the New Orleans District.

50. Additional tests were conducted with the high gate bays reproduced in the 1:36-scale section model for various flow conditions to determine the velocity and stilling basin performance for existing and future tailwater conditions. These test conditions are illustrated in a film entitled "Old River Low-Sill Control Structure--Existing Stilling Basin Performance for Controlled Flow--High Bays."

Placement of stone protection

51. Tests were conducted simulating a scour hole that developed upstream of the three low gate bays in order to develop guidance for

placing stone in the area. The scour hole extended approximately 40 ft upstream from the edge of the structure (sta 99+48.17) for a maximum width of 165 ft and a maximum depth of 12 ft. These tests required that the upstream approach channel be modified to simulate the existing scour hole. Stone simulating prototype weight (ranging from 2,000 to 16,000 lb) was dropped in the approach channel for a headwater elevation of 49.5 and a tailwater elevation of 46.0 to determine the required distance upstream from the structure from which stone should be dropped to fill the scour hole. Results obtained in the 1:36-scale section model are tabulated below and plotted in Plate 71.

Average Weight of Stone, lb	Length Upstream Measured from Front of Structure, L, ft	Depth of Flow in Channel, D, ft	$\frac{L}{D}$
800	98.0	54.5	1.79
1,560	78.0	54.5	1.43
5,000	63.0	54.5	1.15
13,000	48.0	54.5	0.88

52. The test results and data analysis tabulated above were obtained with the low gate bays fully open. It is anticipated that operation of the low-sill control structure to provide orifice flow control will eliminate the tendency for scour to develop upstream of the structure.

PART IV: DISCUSSION AND RESULTS

53. The hydraulic model investigation of the existing Old River Low-Sill Control Structure revealed that operational modifications would be required to develop a satisfactory means of regulating the structure to achieve the desired flow distribution without creating adverse hydraulic conditions. The existing spillway crest, piers, and stilling basin for both the low and high gate bays were satisfactory, and no alterations were made during the model investigation.

54. Results of tests to determine the discharge characteristics of the low-sill structure indicated that the four possible flow conditions can be satisfied by the following equations:

a. Free uncontrolled flow:

$Q = CLH^{3/2}$, where C is a function of H

b. Submerged uncontrolled flow:

$Q = C_s Lh \sqrt{2g\Delta H}$, where C_s is a function of h/H

c. Free controlled flow:

$Q = C_g LG_o \sqrt{2gH_g}$, where C_g is a function of H_g and G_o

d. Submerged controlled flow:

$Q = C_{g_s} Lh \sqrt{2g\Delta H}$, where C_{g_s} is a function of h/G_o

The discharge coefficients applicable to each of these flow conditions and equations are shown in the respective plates relating the coefficients and the pertinent variable. The limit of each flow regime and the corresponding discharge equation are shown in graphic plots in terms of dimensionless quantities.

55. The trend of the submerged uncontrolled-flow discharge coefficients was substantiated by comparing measured quantities determined from the 1:120-scale general model with computed or predicted quantities determined from the section model data analysis and with test results obtained from previous model investigations.

56. An analysis of the results obtained for controlled-flow

conditions indicated that partial closure of the gate bays from the top of the structure (orifice flow under the gates) would be the most effective method for regulating the structure and maintaining satisfactory stilling basin performance and is therefore the recommended plan of regulating the structure.

57. In the past, the procedure for operating the existing low-sill structure was with the gate bays in the fully open position or an arrangement of fully open and closed gate bays. Results of tests conducted with one gate bay fully closed and adjacent bays open indicated severe turbulence was induced upstream of the fully closed gate. Substantial results have been obtained with the 1:120-scale (three-dimensional) fixed-bed model which support the results of the 1:36- and 1:150-scale section models. Therefore, the method of regulating the structure by means of fully closing various gate bays should be discontinued for headwaters in excess of el 37.0 and implemented only under emergency conditions with headwaters less than el 37.0.

58. The Froude number of flow in the exit channel downstream of the low bays should not exceed 0.5 for any gate opening. Likewise, the Froude number of flow in the exit channel downstream of the high bays should not exceed 0.4 for gate openings equal to or less than 11.25 ft and 0.5 for gate openings greater than 11.25 ft.

59. Pressures obtained for a range of flow conditions indicated no serious negative pressures should be encountered on boundaries of the prototype subject to flow.

60. Results of limited tests conducted to investigate instantaneous and continuous dynamic loads or vertical forces exerted on the gate leaves during their installation are supported by results obtained from gate loading tests conducted on the prototype structure. Results of the prototype tests are presented in TR H-76-15 (see paragraph 45).

61. Estimates of the horizontal force induced on the gate leaves for orifice flow operations are tabulated in Tables 20 and 21.

Table 1

Comparison of Uncontrolled-Flow Data Obtained in the 1:36-Scale Section Model and the 1:120-Scale Fixed-Bed Model

Test No.	Gate Bays	No. of Gate Bays Open	HW	TW	H	h	ΔH	$\frac{h}{H}$	Flow Conditions	Discharge Coefficient	Q/Bay, cfs 1:36 Model	Total Discharge, cfs 1:36 Model	Total Discharge, cfs 1:120 Model
1	Low	2	31.9	21.8	36.9	26.8	10.1	0.726	FU	2.95	29,094	155,240	162,000
	High	6	31.9	21.8	21.9	11.8	10.1	0.539	FU	3.58	16,175		
2	Low	2	32.9	19.4	37.9	24.4	13.5	0.644	FU	2.96	30,388	130,000	140,000
	High	4	32.9	19.4	22.9	9.4	13.5	0.410	FU	3.59	17,310		
3	Low	3	32.1	21.5	37.1	26.5	10.6	0.714	FU	2.95	29,291	153,500	160,000
	High	4	32.1	21.5	22.1	11.5	10.6	0.520	FU	3.58	16,401		
4	Low	3	32.1	21.4	37.1	26.5	10.6	0.711	FU	2.95	29,291	153,500	158,000
	High	4	32.1	21.4	22.1	11.4	10.6	0.510	FU	3.58	16,401		
5	Low	2	32.9	19.3	37.9	24.3	13.6	0.644	FU	2.96	30,388	130,000	139,000
	High	4	32.9	19.3	22.9	9.3	13.6	0.410	FU	3.59	17,310		
6	Low	1	35.0	22.0	40.0	27.0	13.0	0.675	FU	2.98	33,240	152,000	151,000
	High	6	35.0	22.0	25.0	12.0	13.0	0.48	FU	3.60	19,800		
7	Low	2	40.0	27.0	45.0	32.0	13.0	0.711	FU	3.10	41,268	187,400	174,000
	High	4	40.0	27.0	30.0	17.0	13.0	0.567	FU	3.62	26,22		
8	Low	2	45.0	32.0	50.0	37.0	13.0	0.740	SU	1.0	47,105	225,270	211,000
	High	4	45.0	32.0	35.0	22.0	13.0	0.630	SU	1.17	32,770		
9	Low	2	50.0	37.0	55.0	42.0	13.0	0.763	SU	1.0	53,470	267,800	245,000
	High	4	50.0	37.0	40.0	27.0	13.0	0.675	SU	1.17	40,217		
10	Low	1	55.0	42.0	60.0	47.0	13.0	0.783	SU	1.0	59,836	345,830	313,000
	High	6	55.0	42.0	45.0	32.0	13.0	0.711	SU	1.17	47,665		
11	Low	1	60.0	47.0	65.0	52.0	13.0	0.80	SU	1.0	66,201	396,880	362,000
	High	6	60.0	47.0	50.0	37.0	13.0	0.74	SU	1.17	55,113		
12	Low	3	30.0	22.2	35.0	27.2	7.8	0.77	SU	1.0	26,820	150,000	157,000
	High	5	30.0	22.2	20.0	12.2	7.8	0.61	FU	3.576	14,070		
13	Low	3	43.5	34.4	48.5	39.4	9.1	0.812	SU	1.0	41,967	308,350	293,000
	High	6	43.5	34.4	33.5	24.4	9.1	0.728	SU	1.17	30,408		
14	Low	3	35.0	27.3	40.0	32.3	7.7	0.807	SU	1.0	31,647	194,100	192,000
	High	5	35.0	27.3	25.0	17.3	7.7	0.692	SU	1.17	19,832		
15	Low	3	40.0	32.5	45.0	37.5	7.5	0.833	SU	1.0	36,262	236,070	225,000
	High	5	40.0	32.5	30.0	22.5	7.5	0.75	SU	1.17	25,456		
16	Low	3	44.0	39.8	49.0	44.8	4.2	0.914	SU	1.0	32,418	299,090	316,000
	High	8	44.0	39.8	34.0	29.8	4.2	0.876	SU	1.17	25,230		

Note: FU = Free uncontrolled flow; SU = Submerged uncontrolled flow. Elevations are in feet referred to mean sea level.

Table 2

Comparison of Controlled-Flow Data Obtained in the 1:36-Scale Section Model and the 1:120-Scale Fixed-Bed Model

Test No.	Gate Bays	No. of Gate Bays Open	HW	TW	H	h	G_o	$\frac{h}{H}$	$\frac{H}{G_o}$	Flow Conditions	$\frac{h}{G_o}$	Discharge Coefficient	Q/Bay, cfs 1:36 Model	Total Discharge, cfs 1:36 Model	Total Discharge, cfs 1:120 Model
1	Low	3	44.0	38.0	49.0	43.0	24.86	0.877	1.97	SC	1.73	0.442	16,438	275,990	277,000
	High	8	44.0	38.0	34.0	28.0	Open	0.824	--	SU	--	1.17	28,334		
2	Low	3	40.0	34.0	45.0	39.0	24.86	0.867	1.81	SC	1.57	0.490	16,528	243,890	243,000
	High	8	40.0	34.0	30.0	24.0	Open	0.80	--	SU	--	1.17	24,286		
3	Low	3	44.0	34.4	49.0	39.4	24.86	0.80	1.97	SC	1.58	0.487	20,992	250,370	235,000
	High	6	44.0	34.4	34.0	24.4	Open	0.717	--	SU	--	1.17	31,230		
4	Low	3	44.0	31.0	49.0	36.0	24.86	0.73	1.97	SC	1.45	0.544	24,930	199,900	191,000
	High	4	44.0	31.0	34.0	21.0	Open	0.617	--	SU	--	1.17	31,280		
5	Low	3	42.0	32.5	47.0	37.5	24.86	0.798	1.89	SC	1.51	0.511	20,850	234,440	228,000
	High	6	42.0	32.5	32.0	22.5	Open	0.703	--	SU	--	1.17	28,650		
6	Low	3	42.0	29.0	47.0	34.0	24.86	0.723	1.89	SC	1.37	0.646	27,960	197,100	185,000
	High	4	42.0	29.0	32.0	19.0	Open	0.594	--	SU	--	1.17	28,300		
7	Low	3	40.0	30.9	45.0	35.9	24.86	0.798	1.81	SC	1.44	0.549	21,000	219,280	208,000
	High	6	40.0	30.9	30.0	20.9	Open	0.697	--	SU	--	1.17	26,050		
8	Low	3	40.0	27.0	45.0	32.0	24.86	0.711	1.81	SC	1.28	0.643	26,195	183,270	180,000
	High	4	40.0	27.0	30.0	17.0	Open	0.567	--	FU	--	3.62	26,172		
9	Low	3	38.0	26.0	43.0	31.0	24.86	0.721	1.73	SC	1.24	0.672	25,481	170,840	170,000
	High	4	38.0	26.0	28.0	16.0	Open	0.571	--	FU	--	3.62	23,599		
10	Low	3	36.0	25.5	41.0	30.5	24.86	0.744	1.65	SC	1.22	0.686	23,940	156,000	160,000
	High	4	36.0	25.5	26.0	15.5	Open	0.596	--	FU	--	3.61	21,060		

Note: SC = Submerged controlled flow; FU = Free uncontrolled flow; SU = Submerged uncontrolled flow. Elevations are in feet referred to mean sea level.

Table 3

Comparison of Data Obtained in the 1:36-Scale Section Model and the 1:120-Scale Fixed-Bed Model

Test No.	Gate Bays	No. of Gate Bays Open	HW	TW	G_o	h	H	$\frac{h}{G_o}$	$\frac{H-h}{G_o}$	Flow Conditions	$\frac{h}{H}$	$\frac{H}{G_o}$	Flow Conditions	Discharge Coefficient	Q/Bay, cfs 1:36 Model	Total Discharge, cfs 1:36 Model	Total Discharge, cfs 1:120 Model
1	Low	3	41.8	27.8	24.75	32.8	46.8	1.32	0.57	SC	0.7	1.89	SC	C_{gs} = 0.614	26,600	79,780	85,000
2	Low	3	52.6	43.0	24.75	48.0	57.6	1.94	0.39	SC	0.83	2.32	SC	C_{gs} = 0.390	20,467	268,070	270,000
	High	8	52.6	43.0	24.75	33.0	42.6	1.33	0.39	SC	0.77	1.72	SC	C_{gs} = 0.716	25,833		
3	Low	3	51.1	46.6	47.0	51.6	56.1	1.09	0.09	SU	0.92	1.19	SU	C_s = 1.0	38,650	308,800	336,000
	High	8	51.1	46.6	32.6	36.6	41.1	1.12	0.14	SC	0.89	1.26	SC	C_{gs} = 0.88	24,109		
4	Low	3	40.8	31.4	24.75	36.4	45.8	1.47	0.37	SC	0.79	1.85	SC	C_{gs} = 0.533	20,990	117,180	121,000
	High	2	40.8	31.4	Open	21.4	30.8	--	--	--	0.69	--	SU	C_s = 1.17	27,100		
5	Low	2	41.0	30.1	24.75	35.1	46.0	1.42	0.44	SC	0.76	1.85	SC	C_{gs} = 0.546	22,330	99,450	104,000
	High	2	41.0	30.1	Open	20.1	31.0	--	--	--	0.65	--	SU	C_s = 1.17	27,400		
6	Low	3	45.8	39.2	24.75	44.2	50.8	1.78	0.27	SC	0.87	2.05	SC	C_{gs} = 0.426	17,069	226,980	245,000
	High	8	45.8	39.2	24.75	29.2	35.8	1.17	0.27	SC	0.81	1.45	SC	C_{gs} = 0.83	21,971		
7	Low	3	52.0	41.5	28.83	46.5	57.0	1.61	0.36	SC	0.82	1.97	SC	C_{gs} = 0.48	25,522	294,980	298,000
	High	8	52.0	41.5	24.75	31.5	42.0	1.27	0.42	SC	0.75	1.70	SC	C_{gs} = 0.758	27,300		
8	Low	3	51.4	40.0	28.83	45.0	56.4	1.56	0.40	SC	0.79	1.95	SC	C_{gs} = 0.493	26,432	310,920	333,000
	High	8	51.4	40.0	24.75	30.0	41.4	1.21	0.46	SC	0.72	1.70	SC	C_{gs} = 0.81	28,952		
9	Low	3	51.4	38.0	24.75	42.0	56.4	1.70	0.58	SC	0.74	2.30	SC	C_{gs} = 0.442	24,455	327,990	340,000
	High	8	51.4	38.0	24.75	28.0	41.4	1.13	0.54	SC	0.68	1.70	SC	C_{gs} = 0.878	31,792		
10	Low	3	51.8	36.0	24.75	41.0	56.8	1.65	0.64	SC	0.72	2.29	SC	C_{gs} = 0.465	26,742	297,175	305,00
	High	8	51.8	36.0	20.17	26.0	41.8	1.29	0.78	SC	0.62	2.07	SC	C_{gs} = 0.744	27,118		
11	Low	3	40.0	23.0	20.17	28.0	45.0	1.39	0.84	SC	0.62	2.23	SC	C_{gs} = 0.577	23,506	177,000	190,000
	High	8	40.0	23.0	11.25	13.0	30.0	1.16	1.51	SC	0.43	2.66	SC	C_{gs} = 0.68	13,327		
12	Low	1	41.5	21.0	11.25	26.0	46.5	2.31	1.82	SC	0.56	4.13	SC	C_{gs} = 0.324	13,460	123,300	137,000
	High	8	41.5	21.0	11.25	11.0	31.5	0.97	1.91	FC	0.34	2.8	FC	C_g = 0.68	13,731		

Note: FC = Free controlled flow; SC = Submerged controlled flow; FU = Free uncontrolled flow; SU = Submerged uncontrolled flow. Elevations are in feet referred to mean sea level.

Table 4

Gate Openings for Operation of Vertical-Lift Gates

Low Gate Bays Crest El -5.0		High Gate Bays Crest El +10.0	
Elevation of Bottom Lip of Gate Leaf	Gate Opening G_o	Elevation of Bottom Lip of Gate Leaf	Gate Opening G_o
68.27	73.27	68.19	58.19
64.65	69.65	64.57	54.57
61.07	66.07	60.86	50.86
57.44	62.44	57.15	47.15
49.57	54.57	53.53	43.53
45.86	50.86	46.19	36.19
42.15	47.15	42.69	32.69
38.53	43.53	38.94	28.94
31.19	36.19	34.86	24.86
27.69	32.69	29.28	19.28
23.94	28.94	24.65	14.65
19.86	24.86	21.36	11.36
14.28	19.28	17.36	7.36
9.65	14.65	14.20	4.20
6.36	11.36		
2.36	7.36		
-0.80	4.20		

Note: All elevations are in feet referred to mean sea level.

Table 5

Froude Number of Flow in Exit Channel for Low Gate Bays

Hydraulic Jump

G_o	HW	TW	Q	D	A	$\overline{V}$	$\sqrt{gD}$	Fn
4.0	24	2.0	7,132	10.0	720	9.9	17.9	0.55
4.0	30	4.0	7,960	12.0	864	9.2	19.7	0.46
4.0	40	4.0	9,020	12.0	864	10.4	19.7	0.53
4.0	52	7.0	10,890	15.0	1080	10.1	21.9	0.46
11.25	24	10.5	19,964	18.5	1332	14.9	24.4	0.61
11.25	30	12	20,333	20	1440	14.1	25.3	0.58
11.25	40	15	25,854	23	1656	15.6	27.2	0.57
11.25	52	18.5	29,454	26.5	1908	15.4	29.2	0.53
20.17	30	19.5	32,923	27.5	1980	16.6	29.8	0.56
20.17	40	22.0	42,675	30	2160	19.8	31.0	0.64
20.17	52	26.0	48,775	34	2448	19.9	33.0	0.60
20.17	60	32.0	50,524	40	2880	17.5	35.9	0.49
20.17	65	34.0	51,333	42	3024	17.0	36,8	0.46
24.75	30	22.5	36,700	30.5	2196	16.7	31.3	0.53
24.75	40	25	45,820	33	2376	19.3	35.6	0.54
24.75	52	28.5	53,525	36.5	2628	20.4	34.3	0.59
24.75	60	36	59,650	44	3168	18.8	37.6	0.50
24.75	65	38	66,140	46	3312	20.0	38.4	0.52
28.83	40	29.5	49,054	37.5	2700	18.2	34.7	0.52
28.83	52	33	59,650	41	2952	20.2	36.3	0.56
28.83	60	38.5	67,020	46.5	3348	20.0	38.7	0.52
28.83	65	41.0	70,440	49	3528	20.0	39.7	0.51
36.19	52	38.5	75,300	46.5	3348	22.5	38.7	0.58
36.19	60	44.0	79,890	52	3744	21.3	40.9	0.52
36.19	65	47.0	83,818	55	3960	20.9	42.0	0.50
43.53	52	44	85,656	52	3744	22.9	40.9	0.56
43.53	60	49.5	85,656	57.5	4140	20.7	43	0.48
43.53	65	52.5	85,656	59.5	4284	20.0	43.8	0.47

Hydraulic Jump, Standing Wave in the Exit Channel

G_o	HW	TW	Q	D	A	$\overline{V}$	$\sqrt{gD}$	Fn
4.0	24	2.0	7,132	10.0	720	9.9	17.9	0.55
4.0	30	4.0	7,960	12.0	864	9.2	19.7	0.45
4.0	40	4.0	9,020	12.0	864	10.4	19.7	0.53
4.0	52	7.0	10,890	15.0	1080	10.1	21.9	0.46
11.25	24	10.5	19,964	18.5	1332	15.0	24.4	0.61
11.25	30	13.0	20,333	21.0	1512	13.4	26.0	0.52
11.25	40	13.0	25,854	21.0	1512	17.1	26.0	0.66
11.25	52	16.5	30,231	24.5	1764	17.1	28.1	0.61
20.17	30	19.0	32,923	27.0	1944	16.9	29.5	0.57
20.17	40	21.0	42,675	29.0	2088	20.4	30.6	0.67
20.17	52	24.0	49,630	32.0	2304	21.5	32.0	0.67
20.17	60	31.0	52,333	39.0	2808	18.6	35.4	0.53
20.17	65	32.0	55,635	40.0	2880	19.3	35.9	0.54
24.75	30	22.0	36,725	30.0	2160	17.0	31.1	0.55
24.75	40	24.0	50,205	32.0	2304	21.8	32.0	0.68
24.75	52	27.5	54,590	35.5	2556	21.4	33.8	0.63
24.75	60	35.0	61,570	43.0	3096	19.9	37.2	0.53
24.75	65	36.0	64,350	44.0	3168	20.3	37.6	0.54
28.83	40	27.0	52,440	35.0	2520	20.8	33.6	0.62
28.83	52	31.5	63,434	39.5	2844	22.3	35.7	0.62
28.83	60	38.0	67,900	46.0	3312	20.5	38.5	0.53
28.83	65	39.0	75,300	47.0	3384	22.3	38.9	0.57
36.19	52	37.0	78,386	45.0	3240	42.2	38.0	0.64
36.19	60	42.0	85,656	50.0	3600	23.8	40.1	0.59
36.19	65	43.0	91,430	51.0	3672	24.9	40.5	0.61
43.53	52	41.0	92,885	49.0	3528	26.3	39.7	0.66
43.53	60	47.0	97,320	55.0	3960	24.6	42.1	0.58
43.53	65	46.0	109,706	54.0	3888	28.2	41.7	0.68

Forced Jump, Supercritical Flow in the Exit Channel

G_o	HW	TW	Q	D	A	$\overline{V}$	$\sqrt{gD}$	Fn
4.0	24	1.0	6,220	9.0	648	9.6	17.0	0.56
4.0	30	1.0	7,958	9.0	648	12.3	17.0	0.72
4.0	40	1.5	9,016	9.5	684	13.2	17.4	0.76
4.0	52	2.0	10,890	10	720	15.1	17.9	0.84
11.25	24	2.5	19,964	10.5	75	26.4	18.4	1.43
11.25	30	6.0	22,431	14	1008	22.3	21.2	1.05
11.25	40	8.0	25,854	16	1152	22.4	22.7	0.98
11.25	52	12.0	30,231	20	1440	21.0	25.4	0.82
20.17	30	12.0	36,725	20	1440	25.5	25.4	1.00
20.17	40	14.0	44,510	22	1584	28.0	26.6	1.05
20.17	52	20.0	49,581	28	2016	24.6	30.0	0.82
20.17	60	22.0	54,590	30	2160	25.2	31.1	0.81
20.17	65	24.0	56,663	32	2304	24.6	32	0.76
24.75	30	14.0	42,300	22	1584	26.7	26.6	1.00
24.75	40	17.5	46,673	25.5	1836	25.4	28.6	0.89
24.75	52	24.5	57,681	32.5	2340	24.6	32.3	0.76
24.75	60	29.3	66,140	37.5	2700	24.5	34.8	0.70
24.75	65	31.0	68,750	39.0	2808	24.5	35.4	0.69
28.83	40	20	59,645	28	2016	29.6	30.0	0.98
28.83	52	29	65,454	37	2664	24.6	34.5	0.71
28.83	60	32	75,300	40	2880	26.1	35.8	0.73
28.83	65	35	79,141	43	3096	25.6	37.2	0.69
36.19	52	34.5	82,095	42.5	3060	26.8	33.7	0.79
36.19	60	36.0	90,623	44.0	3168	28.6	37.6	0.76
36.19	65	38.0	94,970	46.0	3312	28.7	38.4	0.75
43.53	52	39.0	98,484	47	3384	29.1	38.9	0.75
43.53	60	42.0	106,353	50	3600	29.5	40.1	0.74
43.53	65	42.0	109,706	50	3600	30.5	40.0	0.76

Note: Q = total discharge through the section model (1.67 gate bays).
D = depth of flow in exit channel measured 100 ft below end sill.
A = area in exit channel (D × width of section model).
$\overline{V}$ = average velocity.
Elevations are in feet referred to mean sea level.

Table 6

Froude Number of Flow in Exit Channel for High Gate Bays

Hydraulic Jump, Standing Wave in the Exit Channel									Forced Jump, Supercritical Flow in the Exit Channel								
G_o	HW	TW	Q	D	A	$\bar{V}$	$\sqrt{gD}$	Fn	G_o	HW	TW	Q	D	A	$\bar{V}$	$\sqrt{gD}$	Fn
6.0	30	13.5	10,017	15.5	1116	8.97	22.3	0.40	6.0	30	11.0	10,017	13	936	10.7	20.4	0.52
6.0	40	17.0	12,260	19.0	1368	8.96	24.7	0.36	6.0	40	11.5	12,260	13.5	972	12.6	20.8	0.61
11.25	30	20.0	9,552	22	1584	6.03	26.6	0.22	11.25	30	17.0	16,748	19	1368	12.2	24.7	0.49
11.25	40	23.0	21,750	25	1800	12.0	28.3	0.42	11.25	40	19.0	21,750	21	1512	14.4	26.0	0.55
11.25	52	28.0	26,451	30	2160	12.2	31.0	0.39	11.25	52	23.0	26.450	25	1800	14.7	28.3	0.52
11.25	60	32.0	29,200	34	2448	11.9	33.0	0.36	11.25	60	26.0	30,230	28	2016	15.0	30.0	0.50
11.25	65	32.0	30,737	34	2448	12.6	33.0	0.38	11.25	65	26.0	32,209	28	2016	15.9	30.0	0.53
11.25	70	37.0	29,719	39	2808	10.6	35.4	0.30	11.25	70	29.0	33,622	31	2232	15.0	31.6	0.48
20.17	40	30.0	35,205	32	2304	15.3	32.0	0.48	20.17	40	26.0	36,510	28	2016	18.1	30.0	0.60
20.17	52	34.0	40,196	36	2592	15.5	34.0	0.46	20.17	52	30.0	42,675	32	2304	18.5	32.1	0.58
20.17	60	38.0	50,205	40	2880	17.4	35.8	0.49	20.17	60	32.0	50,205	34	2448	20.5	33.0	0.62
20.17	65	40	53,525	42	3024	17.7	36.8	0.48	20.17	65	35.0	54,590	37	2664	20.5	34.5	0.59
20.17	70	42	55,635	44	3168	17.6	37.7	0.47	20.17	70	35.0	56,663	37	2664	21.3	34.5	0.62
24.75	52	39.0	51,333	41	2952	17.4	36.3	0.48	24.75	52	36.0	52,440	38	2736	19.1	34.9	0.55
24.75	60	42.0	58,670	44	3168	18.5	37.7	0.49	24.75	60	37.0	61,570	39	2808	22.0	35.4	0.62
24.75	65	43.0	67,020	45	3240	20.7	38.0	0.55	24.75	65	39.0	67,020	41	2952	22.7	36.3	0.62
24.75	70	45.0	69,600	47	3384	20.6	38.9	0.53	24.75	70	39.0	69,600	41	2952	23.6	36.3	0.65
28.83	52	42.0	57,675	44	3168	18.2	37.7	0.48	28.83	52	39.5	58,670	41.5	2988	19.6	36.5	0.54
28.83	60	44.5	63,434	46.5	3348	18.9	38.7	0.49	28.83	60	40.0	67,890	42	3024	22.4	36.7	0.61
28.83	65	46.0	70,440	48.0	3456	20.4	39.3	0.52	28.83	65	42.0	72,092	44	3168	22.8	37.7	0.60
28.83	70	48.0	73,712	50.0	3600	20.5	40.1	0.51	28.83	70	42.0	76,857	44	3168	24.3	37.7	0.64
36.19	60	50.0	76,857	52	3744	20.5	40.9	0.50	36.19	60	44.5	83,178	46.5	3348	24.8	38.7	0.64
36.19	65	52.0	85,656	54	3888	22.0	41.7	0.53	36.19	65	47.0	88,455	49	3528	25.0	39.7	0.63
36.19	70	52.0	93,944	54	3888	24.1	41.7	0.58	36.19	70	46.0	95,443	48	3456	27.6	39.3	0.70

Note: Q = total discharge through the section model (1.67 gate bays).
D = depth of flow in exit channel measured 100 ft below end sill.
A = area in exit channel (D × width of section model).
$\bar{V}$ = average velocity.
Elevations are in feet referred to mean sea level.

Table 7

Pressures on Spillway Crest and Stilling Basin

Apron, Low Gate Bays (Crest El -5.0; HW 30.0, 40.0, and 52.0)

Piezometer		Pressure in Prototype Feet of Water for Uncontrolled Flow										
		HW = 30.0 Tailwater El				HW = 40.0 Tailwater El				HW = 52.0 Tailwater El		
No.	El	28.0	23.5	21.0	17.0	35.0	32.0	28.0	24.0	49.0	46.5	41.0
1	-5	34.0	32.0	32.0	32.5	43.0	42.5	41.0	40.5	55.0	55.0	51.0
2	-5	33.0	31.0	31.0	31.5	42.0	41.5	40.0	39.5	54.0	54.0	49.0
3	-5	32.5	30.0	29.3	29.8	41.0	39.5	37.5	37.5	53.5	52.0	46.5
4	-5	32.0	29.0	28.8	28.8	40.0	38.0	36.5	36.5	53.0	41.5	46.0
5	-5	31.5	27.8	27.0	26.5	39.0	37.0	34.5	35.0	52.3	50.0	44.0
6	-5.75	31.25	25.75	24.75	23.75	37.25	34.75	31.75	33.25	51.75	47.75	41.25
7	-5.47	30.97	24.47	23.47	22.47	36.47	33.47	30.47	30.97	51.47	47.47	40.47
8	-7.02	33.02	28.02	26.52	26.02	39.52	37.02	34.02	33.52	54.02	51.02	45.02
9	-8.81	35.81	30.31	28.81	28.31	41.81	39.81	36.81	36.31	56.81	53.81	47.81
10	-11.2	39.2	33.7	32.2	31.5	45.7	43.2	40.2	40.2	59.7	57.7	52.2
11	-12	40.5	36.5	35.5	34.5	48.0	46.0	44.0	43.0	61.5	60.0	56.0
12	-12	41.0	37.0	35.8	35.0	49.0	47.0	44.5	44.0	62.0	61.0	57.0
13	-12	41.5	37.5	36.0	35.0	49.5	47.0	44.0	43.5	62.0	61.0	56.0
14	-12	41.8	39.0	38.0	37.0	50.0	48.5	46.0	45.5	63.0	60.0	58.0
15	-12	41.8	38.5	37.0	36.0	49.0	48.5	44.5	44.0	62.0	61.0	56.0
16	-12	40.5	37.0	35.0	34.0	48.0	45.0	42.0	43.0	62.0	60.0	54.0
17	-12	40.0	35.0	33.0	31.8	46.0	43.0	39.5	39.0	61.0	58.0	52.0
18	-12	41.0	37.0	35.0	33.5	47.5	44.0	42.0	41.0	61.5	59.0	52.0

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level.
HW = headwater.

Table 8

Pressures on Spillway Crest and Stilling Basin Apron

Piezometer		Pressure in Prototype Feet of Water for Uncontrolled Flow					
		HW = 15.0 Tailwater El		HW = 20.0 Tailwater El		HW = 25.0 Tailwater El	
No.	El	7.0	1.0	12.0	9.0	17.5	13.0
		Gate Leaf 4L Installed on Lower Sill (Weir El +10.0)					
1	-5	20.0	20.0	25.0	25.0	30.0	30.0
2	-5	20.0	20.0	25.0	25.0	30.0	30.0
3	-5	20.0	20.0	25.0	25.0	30.0	30.0
4	-5	20.0	20.0	25.0	25.0	30.0	30.0
5	-5	20.0	20.0	25.0	25.0	30.0	30.0
6	-5.75	17.75	17.25	22.25	20.25	26.75	22.75
7	-5.47	12.77	11.97	16.97	13.47	21.47	13.47
8	-7.02	14.52	15.52	19.02	16.02	23.52	16.02
9	-8.81	16.31	10.31	20.81	17.81	25.31	17.81
10	-11.2	19.2	11.7	23.2	21.2	27.7	20.2
11	-12	19.0	13.0	25.0	23.0	28.5	25.0
12	-12	19.0	13.0	27.0	21.0	28.5	25.0
13	-12	18.8	13.5	24.0	20.5	32.0	20.0
14	-12	19.0	14.0	24.0	21.5	30.5	21.5
15	-12	19.5	14.0	25.0	22.0	30.5	22.5
16	-12	19.5	14.0	25.0	22.0	30.5	22.5
17	-12	19.5	14.0	25.0	21.5	30.0	21.0
18	-12	19.5	14.0	25.0	21.8	30.0	22.0

Piezometer		Pressure in Prototype Feet of Water for Uncontrolled Flow										
		HW = 32.0 Tailwater El			HW = 37.0 Tailwater El				HW = 42.0 Tailwater El			
No.	El	27.0	20.0	5.0	29.0	23.0	15.0	0.0	37.0	28.0	21.0	13.0
		Gate Leaves 4L and 3L Installed on Lower Sill (Weir El +29.0)										
1	-5	37.0	37.0	37.0	42.0	42.0	42.0	42.0	47.0	47.0	47.0	47.0
2	-5	37.0	37.0	37.0	42.0	42.0	42.0	42.0	47.0	47.0	47.0	47.0
3	-5	37.0	37.0	37.0	42.0	42.0	42.0	42.0	47.0	47.0	47.0	47.0
4	-5	37.0	37.0	37.0	42.0	42.0	42.0	41.8	47.0	47.0	47.0	47.0
5	-5	37.0	37.0	37.0	42.0	42.0	42.0	29.75	47.0	47.0	47.0	47.0
6	-5.75	36.55	32.75	25.75	39.55	37.05	34.25	16.47	44.75	40.75	38.25	34.75
7	-5.47	33.97	25.47	9.47	34.27	28.97	22.47	18.02	40.97	32.47	25.97	17.75
8	-7.02	35.82	27.52	13.52	36.02	31.02	24.52	20.81	43.02	34.52	29.02	21.52
9	-8.81	37.61	29.31	15.31	37.81	32.81	26.31	11.5	44.81	36.31	30.31	23.31
10	-11.2	40.0	31.7	18.2	40.0	35.7	31.2	12.1	47.2	38.0	31.7	25.7
11	-12	40.8	32.3	17.0	41.0	37.0	28.0	12.2	48.0	40.0	33.8	27.0
12	-12	40.8	32.0	17.0	42.0	37.0	27.0	12.3	48.0	44.0	42.0	39.0
13	-12	40.8	32.0	17.5	41.0	35.0	26.0	12.38	48.0	41.0	34.5	24.0
14	-12	40.8	32.0	17.5	40.8	34.8	26.5	12.38	48.0	38.5	32.0	24.0
15	-12	40.8	32.0	17.5	41.0	35.5	27.5	12.38	48.0	40.5	33.0	24.5
16	-12	40.8	32.3	17.5	41.0	35.5	27.5	12.35	48.0	40.5	33.5	25.0
17	-12	40.8	32.3	17.8	41.0	35.5	27.5	12.3	48.0	40.0	33.5	25.0
18	-12	40.8	32.3	17.8	41.0	35.5	27.5	12.3	48.0	40.0	33.5	25.5

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level. HW = headwater.

Table 9

Pressures on Spillway Crest and Stilling Basin

Apron, Low Gate Bays (Crest El -5.0, HW 30.0)

Piezometer		Pressure in Prototype Feet of Water														
		G_o = 4.0 Tailwater El				G_o = 11.25 Tailwater El				G_o = 20.17 Tailwater El				G_o = 24.75 Tailwater El		
No.	El	28.0	19.0	15.0	5.0	22.5	16.9	14.0	5.8	24.0	20.0	15.8	11.8	24.8	20.0	14.0
1	-5	35.3	35.0	35.0	36.0	36.0	35.0	35.0	35.5	35.5	35.0	34.5	35.0	35.0	34.5	34.0
2	-5	35.3	35.0	35.0	36.0	35.5	35.0	34.5	35.0	35.0	34.5	34.0	34.5	34.5	33.5	33.0
3	-5	35.3	35.0	34.8	35.6	35.3	34.0	33.8	34.0	34.5	34.0	32.3	33.0	33.8	32.0	32.0
4	-5	35.3	35.0	34.5	35.6	35.0	34.0	33.5	33.5	34.0	33.0	31.8	32.0	33.0	31.0	31.0
5	-5	35.3	34.5	33.5	34.0	33.5	31.0	30.0	29.3	32.5	30.5	28.0	28.0	32.0	29.0	28.0
6	-5.75	35.25	31.25	28.25	22.75	31.25	25.7	24.75	21.25	31.25	27.75	23.8	23.25	31.05	25.75	23.75
7	-5.47	33.97	25.97	20.47	7.47	28.47	21.5	18.5	12.47	29.47	24.9	19.5	18.47	29.47	23.47	20.97
8	-7.02	35.52	27.52	22.02	9.02	30.02	23.02	20.02	13.52	31.32	26.82	22.02	20.5	31.02	25.82	23.52
9	-8.81	37.31	28.81	23.31	9.81	30.81	22.81	20.81	12.81	32.81	27.81	22.81	20.81	32.81	27.31	24.31
10	-11.2	39.70	31.2	25.7	12.7	33.2	25.2	22.7	15.2	35.2	30.2	25.2	23.2	35.7	30.2	26.7
11	-12	40.5	32.5	27.0	15.0	35.3	28.0	26.0	21.5	37.0	33.0	29.0	27.0	37.5	33.5	30.5
12	-12	40.5	32.0	26.5	15.0	34.8	27.0	25.0	30.0	36.5	32.5	28.5	26.8	37.5	33.5	30.0
13	-12	40.5	31.5	26.0	15.5	33.3	26.0	23.5	30.0	35.3	31.5	28.0	25.5	36.5	32.5	29.5
14	-12	40.5	31.5	25.5	17.0	34.0	28.0	26.0	23.5	36.8	33.8	31.5	30.0	38.0	35.5	33.5
15	-12	40.5	31.0	27.0	18.5	35.0	29.0	27.0	24.0	37.0	34.0	31.5	30.0	38.0	35.0	33.0
16	-12	40.5	32.0	27.0	18.0	35.0	29.0	27.0	24.0	36.0	32.5	29.5	28.0	37.0	33.0	30.0
17	-12	40.5	35.2	27.3	17.5	35.0	29.0	26.0	22.0	36.0	32.3	27.5	26.5	36.5	32.0	28.0
18	-12	40.5	35.2	27.5	18.0	35.0	29.5	26.5	23.3	36.3	32.8	29.0	28.0	37.0	33.0	30.0

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level.
HW = headwater and G_o = gate opening.

Table 10

Pressures on Spillway Crest and Stilling Basin

Apron, Low Gate Bays (Crest El -5.0, HW 40.0)

Piezometer		Pressures in Prototype Feet of Water															
		G_o = 4.0 Tailwater El			G_o = 11.25 Tailwater El			G_o = 20.17 Tailwater El				G_o = 24.75 Tailwater El		G_o = 28.83 Tailwater El			
No.	El	28.5	20.0	14.0	36.0	21.2	15.0	37.0	28.5	23.5	15.0	28.0	19.0	35.5	31.0	24.0	20.5
1	-5	46.5	46.0	46.0	44.8	45.5	45.5	45.8	45.5	45.5	45.5	45.0	45.0	45.0	45.0	44.0	45.0
2	-5	46.5	46.0	46.0	44.5	45.3	45.3	45.5	45.0	44.5	44.0	44.5	44.0	45.0	44.0	43.0	44.0
3	-5	46.5	45.8	46.0	44.3	44.5	44.0	45.3	43.8	42.8	42.0	43.0	41.0	44.0	43.0	40.0	41.0
4	-5	46.3	45.5	45.8	44.2	43.8	43.0	45.0	43.0	41.5	40.0	42.0	40.0	44.0	42.0	39.0	39.0
5	-5	45.8	44.5	44.8	43.8	40.0	37.5	44.5	40.0	37.5	35.0	38.8	35.0	42.0	39.0	34.5	35.0
6	-5.75	41.75	37.05	34.25	43.25	32.75	27.75	44.25	36.25	31.25	26.25	35.25	27.75	41.25	36.75	29.25	28.75
7	-5.47	34.47	25.97	18.47	42.27	26.47	17.47	43.27	32.97	26.5	19.47	31.97	21.97	39.97	34.47	25.47	24.97
8	-7.02	36.02	27.52	20.82	43.82	28.02	19.02	44.82	35.02	29.02	22.02	34.52	25.02	42.02	37.02	28.52	27.52
9	-8.81	37.31	28.31	21.31	45.11	27.81	27.81	46.31	35.81	29.81	21.11	35.81	25.31	43.81	38.81	29.81	28.61
10	-11.2	39.7	30.7	23.7	47.5	30.2	30.2	48.7	38.2	32.2	22.2	38.2	27.2	46.2	41.2	32.2	30.7
11	-12	41.0	32.3	25.5	48.5	34.0	26.5	50.0	41.0	36.0	27.8	41.0	32.0	48.0	44.0	36.5	34.5
12	-12	41.0	32.0	25.5	48.5	33.0	25.5	50.0	40.5	34.8	26.5	40.5	31.0	48.0	43.0	36.0	33.5
13	-12	40.0	31.0	24.0	48.0	30.0	23.0	49.3	37.5	32.0	24.0	38.0	29.0	47.0	42.0	34.5	31.5
14	-12	40.0	30.5	24.0	48.0	32.0	27.5	49.8	40.5	37.0	32.0	41.8	36.0	48.0	45.0	39.5	37.5
15	-12	41.0	32.5	27.0	48.5	33.0	28.5	49.8	40.5	37.0	32.0	41.8	36.0	48.0	45.0	39.5	37.5
16	-12	41.0	32.5	26.0	48.5	33.0	28.5	49.3	39.0	34.0	29.0	39.0	32.0	46.5	42.0	35.0	33.0
17	-12	41.0	32.5	26.0	48.5	33.0	27.5	49.3	39.5	34.0	29.0	39.0	31.0	47.0	42.0	34.0	32.0
18	-12	41.0	32.5	26.0	48.5	33.3	28.0	49.5	40.0	35.0	29.8	40.0	32.8	45.5	43.0	35.0	34.0

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level. HW = headwater and G_o = gate opening.

Table 11

Pressures on Spillway Crest and Stilling Basin

Apron, Low Gate Bays (Crest El -5.0, HW 52.0)

Piezometer		Pressure in Prototype Feet of Water																					
		G_o = 4.0 Tailwater El			G_o = 11.25 Tailwater El				G_o = 20.17 Tailwater El			G_o = 24.75 Tailwater El				G_o = 28.83 Tailwater El				G_o = 36.19 Tailwater El		G_o = 43.53 Tailwater El	
No.	El	48.0	40.0	34.5	48.5	43.0	36.0	24.0	48.8	42.5	36.5	48.0	38.0	35.0	28.5	48.0	40.0	36.0	33.5	44.8	37.0	45.0	39.0
1	-5	57.0	57.0	57.5	58.0	51.3	57.0	57.3	57.8	57.0	57.5	58.0	56.0	57.0	56.0	57.0	56.0	57.0	56.0	57.5	56.0	57.0	58.0
2	-5	57.0	57.0	57.3	58.0	57.0	57.0	56.8	57.5	56.5	57.0	58.0	55.0	55.0	53.0	56.8	55.0	56.0	55.0	57.0	55.0	56.0	56.0
3	-5	57.0	57.0	57.3	57.8	56.8	56.3	55.5	57.0	55.5	55.0	57.5	53.0	53.0	50.0	56.0	53.0	53.0	52.0	55.5	53.0	54.0	52.6
4	-5	57.0	57.0	57.2	57.8	56.5	55.5	54.5	56.8	55.0	54.0	57.0	52.0	51.0	48.5	55.8	52.0	52.0	50.0	54.5	50.0	52.5	51.0
5	-5	57.0	56.2	56.3	57.0	55.0	53.0	49.5	56.3	53.0	50.5	56.0	49.0	47.0	42.0	54.8	49.0	47.5	45.0	53.0	45.0	50.0	46.0
6	-5.75	55.92	52.3	49.7	56.25	52.25	47.75	37.75	55.75	50.8	44.75	55.25	45.25	41.75	33.75	54.25	45.25	41.75	38.75	50.75	40.75	48.25	40.75
7	-5.47	54.27	45.97	40.5	54.97	49.47	42.97	28.47	54.47	48.27	41.47	53.8	42.47	37.97	28.47	52.97	42.97	38.47	34.47	48.97	35.97	46.47	37.47
8	-7.02	55.82	47.52	42.02	56.52	51.02	44.52	30.02	56.32	50.02	43.02	55.82	52.82	40.52	32.02	55.02	45.52	41.02	38.02	51.02	40.02	49.52	41.52
9	-8.81	57.61	48.81	43.31	57.81	51.81	44.31	28.81	57.81	51.31	43.81	57.61	45.81	41.81	32.81	56.81	47.31	42.61	38.81	52.81	41.81	51.81	43.31
10	-11.2	59.7	51.2	45.7	60.2	54.2	46.7	31.0	60.2	53.7	46.2	60.0	48.2	44.2	35.2	59.2	49.7	45.0	41.2	55.2	44.7	54.7	47.2
11	-12	60.8	52.8	47.3	61.3	56.0	49.5	36.5	61.8	56.0	50.0	61.3	51.0	47.8	40.0	60.8	52.5	48.5	46.0	57.5	49.0	57.5	52.5
12	-12	60.8	52.3	47.0	61.0	55.5	48.5	35.0	61.5	55.0	49.0	61.0	50.5	46.0	39.0	60.5	51.5	47.5	45.0	57.0	48.5	57.5	52.0
13	-12	60.8	52.0	46.0	60.8	54.0	46.0	31.5	60.8	53.5	46.0	60.0	48.0	43.5	36.0	59.8	49.5	45.0	42.0	55.5	46.5	56.5	50.5
14	-12	60.8	52.0	46.0	61.0	55.0	47.5	34.5	61.5	53.5	49.0	61.0	51.0	48.0	43.0	60.5	53.0	50.0	47.0	58.0	51.5	58.0	54.5
15	-12	60.8	52.5	47.0	61.0	55.8	48.0	36.0	61.5	53.5	49.0	61.0	51.0	48.0	43.0	60.5	53.0	50.0	47.0	57.5	50.0	57.5	53.0
16	-12	60.8	52.5	47.0	61.0	55.0	47.5	35.0	60.5	54.0	47.0	59.5	48.0	44.0	38.0	59.5	49.0	45.5	42.0	54.5	45.0	55.0	48.0
17	-12	60.8	52.3	47.0	61.0	55.0	47.8	35.0	61.5	54.0	47.0	59.5	48.0	44.8	38.0	59.5	49.5	46.0	42.0	54.5	44.0	53.0	45.0
18	-12	60.8	52.5	47.0	61.0	55.0	48.0	35.5	61.5	54.0	47.5	59.8	49.0	45.0	39.0	59.5	49.5	46.0	43.0	55.0	46.0	55.0	48.0

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level. HW = headwater and G_o = gate opening.

Table 12

Pressures on Spillway Crest and Stilling Basin

Apron, Low Gate Bays (Crest El -5.0, HW 60.0)

Piezometer		Pressure in Prototype Feet of Water									
		G_o = 20.17 Tailwater El		G_o = 24.75 Tailwater El		G_o = 28.83 Tailwater El		G_o = 36.19 Tailwater El		G_o = 43.53 Tailwater El	
No.	El	50.0	33.5	48.0	35.0	48.0	36.5	48.8	40.0	55.0	49.5
1	-5	66.0	65.0	66.0	66.0	66.0	66.5	66.5	66.0	65.5	65.5
2	-5	65.0	64.0	65.0	65.0	65.5	64.0	64.5	62.5	65.0	64.0
3	-5	64.5	61.0	64.0	62.0	64.0	59.5	63.5	58.0	64.5	61.0
4	-5	64.0	59.5	63.0	59.5	62.5	58.0	61.5	56.0	63.0	60.0
5	-5	62.0	53.0	60.0	53.0	60.0	51.0	58.5	50.0	62.5	56.5
6	-5.75	59.25	44.75	55.75	44.75	56.75	43.75	55.75	42.75	61.25	53.75
7	-5.47	55.47	36.47	53.47	37.47	53.47	35.47	52.97	37.47	59.97	50.97
8	-7.02	57.52	39.02	55.52	40.2	56.02	39.02	55.52	42.02	62.02	54.52
9	-8.81	58.81	39.81	56.81	40.81	57.31	40.81	57.31	43.81	63.81	56.31
10	-11.2	60.7	41.2	58.7	42.2	59.2	42.7	59.7	46.2	66.2	59.2
11	-12	63.0	46.5	62.0	47.5	62.0	48.5	62.5	52.0	68.0	62.5
12	-12	62.5	44.0	60.5	45.0	61.0	47.0	62.0	51.0	68.0	62.0
13	-12	60.5	38.5	58.5	40.0	59.0	42.0	59.5	48.0	67.0	60.5
14	-12	62.5	46.0	61.0	48.0	62.0	50.5	62.5	54.5	68.0	63.5
15	-12	63.0	47.0	61.0	48.0	62.0	50.0	62.5	54.0	68.0	62.5
16	-12	61.0	42.0	57.5	42.5	57.0	44.0	58.0	46.5	66.0	59.0
17	-12	61.0	43.0	58.5	43.5	58.0	43.5	58.0	45.0	65.0	57.0
18	-12	61.0	43.5	58.0	44.5	58.0	45.0	58.0	47.5	65.5	59.0

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level. HW = headwater and G_o = gate opening.

Table 13

Pressures on Spillway Crest and Stilling Basin

Apron, Low Gate Bays (Crest El -5.0, HW 65.0)

Piezometer		Pressure in Prototype Feet of Water									
		G_o = 20.17 Tailwater El		G_o = 24.75 Tailwater El		G_o = 28.83 Tailwater El		G_o = 36.19 Tailwater El		G_o = 43.53 Tailwater El	
No.	El	54.0	37.0	56.5	40.0	52.0	38.0	51.0	42.5	57.0	50.0
1	-5	71.0	71.0	71.0	70.0	70.0	70.0	70.0	70.0	70.0	69.0
2	-5	70.0	70.0	70.0	69.0	69.0	69.0	69.0	66.5	69.5	67.0
3	-5	69.5	67.0	69.5	66.0	68.0	64.0	66.0	62.5	68.0	64.0
4	-5	69.0	65.0	69.0	64.0	67.0	60.0	65.0	60.0	69.0	63.0
5	-5	66.5	58.5	67.0	58.0	64.0	53.0	61.5	53.5	65.0	58.0
6	-5.75	63.75	48.75	64.75	49.75	61.25	43.75	58.75	45.75	63.25	53.25
7	-5.47	60.47	50.97	62.47	42.97	57.47	37.47	54.97	39.47	61.47	49.97
8	-7.02	62.02	43.02	64.52	46.02	60.02	42.02	58.02	44.02	64.02	54.02
9	-8.81	63.31	43.31	65.81	46.81	60.81	41.81	59.31	46.31	65.81	56.31
10	-11.2	65.2	44.7	67.7	48.2	63.2	44.2	61.7	48.7	68.7	59.2
11	-12	67.5	50.5	70.0	53.0	66.0	50.5	65.0	55.0	70.5	63.5
12	-12	67.0	48.0	69.5	51.0	65.0	48.5	64.0	53.0	70.5	62.5
13	-12	64.5	42.5	68.0	46.0	62.5	43.0	61.5	50.0	69.5	61.0
14	-12	67.5	50.0	70.0	53.0	66.0	52.0	65.0	57.0	71.0	65.0
15	-12	68.0	50.0	70.0	54.0	65.5	52.0	64.5	56.0	70.0	64.0
16	-12	65.0	45.0	68.0	47.0	62.0	45.0	60.0	49.0	67.0	58.0
17	-12	65.0	46.0	68.0	48.5	62.0	44.5	60.0	48.0	66.5	56.0
18	-12	65.0	46.0	67.5	48.5	62.0	46.0	60.0	51.0	67.0	59.0

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level. HW = headwater and G_o = gate opening.

Table 14

Pressures on Spillway Crest and Stilling Basin

Apron, High Gate Bays (Crest El +10.0; HW 30.0, 40.0, 45.0, and 55.0)

Piezometer		Pressure in Prototype Feet of Water for Uncontrolled Flow														
		HW = 30.0 Tailwater El				HW = 40.0 Tailwater El				HW = 45.0 Tailwater El				HW = 55.0 Tailwater El		
No.	El	29.0	27.0	17.0	14.0	37.0	35.0	30.0	26.5	41.5	39.0	37.5	35.0	52.0	47.0	44.0
1	0	29.3	29.3	29.3	29.3	39.0	39.0	38.8	39.0	44.0	43.5	43.5	43.5	53.0	52.0	52.0
2	0	29.3	29.3	29.3	29.3	39.0	39.0	38.8	39.0	44.0	43.5	43.5	43.5	53.0	52.0	52.0
3	0	29.3	29.3	29.3	29.3	39.0	39.0	38.8	39.0	44.0	43.5	43.5	43.5	53.0	52.0	52.0
4	0	29.3	29.3	29.3	29.3	39.5	39.5	40.0	39.0	44.5	44.0	44.0	44.0	53.0	53.0	53.0
5	+2	27.3	27.3	27.3	27.3	37.5	37.5	38.0	37.2	42.5	42.5	42.0	42.0	53.5	52.5	51.0
6	+6	22.0	21.8	21.8	21.8	31.0	31.0	30.0	30.0	36.0	35.0	35.0	35.0	46.0	43.0	42.0
7	+9	13.0	11.0	10.0	10.0	17.0	15.0	13.0	12.0	20.0	16.0	15.0	14.0	26.0	18.0	14.0
8	+10	12.0	10.0	8.5	8.5	17.5	15.0	12.0	11.0	20.0	17.0	16.0	14.0	27.0	18.0	15.0
9	+10	12.0	10.0	7.0	7.0	17.0	14.0	11.0	10.0	20.0	16.0	15.0	14.0	28.0	18.0	15.0
10	+8.6	15.4	13.4	10.2	10.4	21.4	19.4	16.2	15.4	24.4	22.4	20.9	21.4	32.4	25.4	24.4
11	+5.72	20.28	18.28	9.73	9.78	27.3	24.3	19.0	17.28	30.28	27.28	25.3	23.3	40.28	33.28	31.3
12	+3.72	22.78	20.58	10.28	10.28	29.8	26.78	21.0	18.3	32.78	29.8	27.8	25.8	44.28	36.28	34.3
13	+0.75	26.75	24.75	11.25	10.25	34.8	32.25	25.25	19.3	39.25	35.3	33.25	31.25	49.25	43.25	39.25
14	-2	29.5	28.0	14.0	13.5	38.0	36.0	29.0	22.0	42.5	39.0	37.0	35.0	53.0	47.0	44.0
15	-4	32.0	31.0	19.0	18.0	41.0	39.0	34.0	28.5	45.5	42.0	42.0	40.0	55.5	51.0	49.0
16	-5	33.0	32.0	21.0	20.0	42.5	41.0	36.0	31.0	47.0	44.5	44.0	42.0	57.0	53.0	51.0
17	-5	33.5	32.0	23.0	23.0	42.5	41.0	37.0	34.0	47.0	45.0	44.5	43.0	57.5	54.0	51.5
18	-5	33.5	32.0	23.0	23.0	42.0	40.5	36.0	34.0	46.0	44.0	43.5	42.0	57.0	52.0	50.0
19	-5	33.3	31.5	22.0	22.0	42.0	40.0	35.0	31.0	46.0	44.0	43.0	40.0	56.0	51.0	48.0
20	-5	32.5	30.0	19.0	18.0	40.0	37.0	31.0	26.0	44.0	40.0	37.0	36.0	53.0	46.0	42.0
21	-5	33.8	31.0	20.0	19.0	41.0	38.0	32.0	27.0	45.0	41.0	39.0	37.0	54.0	49.0	45.0

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level.
HW = headwater.

Table 15

Pressures on Spillway Crest and Stilling Basin

Apron, High Gate Bays (Crest El +10.0; HW 30.0, 40.0, and 45.0)

Piezometer		Pressure in Prototype Feet of Water																		
		HW = 30.0, G_o = 6.0, Tailwater El		HW = 30.0, G_o = 11.25, Tailwater El				HW = 40.0, G_o = 6.0, Tailwater El			HW = 40.0, G_o = 11.25, Tailwater El				HW = 40.0, G_o = 20.17, Tailwater El			HW = 45.0, G_o = 11.25, Tailwater El		
No.	El	24.0	15.5	29.0	25.0	19.5	3.0	30.0	21.0	11.5	37.5	28.0	19.0	10.0	38.0	34.5	27.0	35.0	27.0	17.0
1	0	30.0	30.0	31.0	31.0	31.0	31.3	40.5	40.5	40.5	41.3	41.0	41.0	41.0	40.0	40.0	40.0	45.5	45.3	45.3
2	0	30.0	30.0	31.0	31.0	31.0	31.3	40.5	40.5	40.5	41.3	41.0	41.0	41.0	40.0	40.0	40.0	45.5	45.3	45.3
3	0	30.0	30.0	31.0	31.0	31.0	31.3	40.5	40.5	40.5	41.3	41.0	41.0	41.0	40.0	40.0	40.0	45.5	45.3	45.3
4	0	30.0	30.0	31.0	31.0	31.0	31.3	40.5	40.5	40.5	41.3	41.0	41.0	41.0	40.0	40.0	40.0	45.5	45.3	45.3
5	+2	29.0	28.0	29.0	29.0	29.0	29.3	38.5	38.5	38.5	39.3	39.0	39.0	39.0	38.0	38.0	38.0	43.5	43.3	43.3
6	+6	24.5	24.5	25.0	24.0	24.0	24.5	34.0	34.0	34.0	35.3	34.0	34.0	34.0	34.0	33.0	32.0	39.0	38.0	38.0
7	+9	20.0	18.5	21.0	18.0	15.0	16.0	29.5	27.5	27.0	30.5	25.0	22.0	22.5	28.5	23.0	17.0	31.0	25.0	25.0
8	+10	17.0	13.0	19.5	15.0	11.5	12.0	25.0	20.0	18.5	28.0	20.5	16.0	16.0	27.0	22.0	15.0	27.0	18.0	17.5
9	+10	13.0	14.5	18.5	13.0	7.0	7.0	19.0	7.0	5.0	27.5	25.5	8.0	7.5	26.5	20.0	11.0	23.0	9.0	8.0
10	+8.6	14.4	3.9	20.4	14.9	8.4	8.2	20.4	7.9	3.9	28.9	17.4	8.4	8.4	28.4	23.4	14.4	24.9	10.4	9.4
11	+5.72	17.3	5.28	23.3	17.8	9.78	6.78	23.28	12.28	4.3	31.58	19.78	7.8	7.6	31.3	26.3	15.3	27.8	14.3	8.3
12	+3.72	19.3	7.3	24.8	19.8	12.3	7.58	25.28	14.8	5.3	33.58	21.8	8.8	8.3	33.3	28.3	17.3	29.8	16.3	8.8
13	+0.75	22.25	12.25	27.7	23.25	16.25	8.25	27.25	18.25	7.25	36.55	24.75	12.25	8.25	36.75	32.25	21.25	32.75	21.25	8.75
14	-2	25.0	15.0	30.5	26.0	18.5	11.0	30.0	21.0	8.0	39.3	28.0	16.0	10.5	39.5	35.5	25.0	35.5	24.0	10.5
15	-4	27.0	19.0	23.0	28.5	23.0	16.0	32.0	23.5	12.0	41.5	31.0	21.0	16.0	42.0	38.5	31.0	38.0	29.0	17.0
16	-5	28.0	20.0	24.0	30.0	25.0	18.0	33.0	25.0	15.0	42.8	32.5	24.0	19.0	43.0	40.0	33.0	40.0	31.0	20.0
17	-5	28.5	21.0	24.3	30.5	26.0	19.0	34.0	25.5	17.0	43.0	34.0	26.5	21.0	43.5	40.0	35.0	41.0	33.0	23.0
18	-5	29.0	21.0	24.3	30.5	26.0	20.0	35.0	27.0	18.5	43.0	34.0	26.5	22.0	43.5	40.0	35.0	41.0	33.0	24.0
19	-5	29.0	23.0	24.3	30.5	26.0	20.0	35.0	27.0	19.0	43.0	34.0	26.5	22.0	43.5	40.0	34.0	41.0	33.0	24.0
20	-5	29.0	19.0	24.0	29.5	24.0	17.0	34.5	26.0	15.0	43.0	32.5	22.0	18.0	43.0	39.0	29.0	39.5	30.0	19.5
21	-5	29.0	20.0	24.0	30.0	24.5	18.0	34.5	26.0	16.0	43.0	33.0	23.0	19.0	43.0	39.0	30.0	40.0	30.0	20.5

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level. HW = headwater and G_o = gate opening.

Table 16

Pressures on Spillway Crest and Stilling Basin

Apron, High Gate Bays (Crest El +10.0; HW 45.0 and 52.0)

Piezometer		Pressure in Prototype Feet of Water																		
		HW = 45.0, G_o = 20.17, Tailwater El			HW = 45.0, G_o = 24.75, Tailwater El			HW = 52.0, G_o = 11.25, Tailwater El				HW = 52.0, G_o = 20.17, Tailwater El			HW = 52.0, G_o = 24.75, Tailwater El			HW = 52.0, G_o = 28.83, Tailwater El		
No.	El	43.0	33.0	23.0	43.5	39.0	27.0	40.5	32.0	25.0	18.0	46.0	38.5	31.0	46.0	38.5	33.5	49.0	44.0	34.0
1	0	45.5	45.5	45.5	45.5	45.5	45.5	53.0	52.3	52.3	52.3	52.0	52.0	52.0	52.0	52.0	52.0	52.5	52.5	52.5
2	0	45.5	45.5	45.5	45.5	45.5	45.5	53.0	52.3	52.3	52.3	52.0	52.0	52.0	52.0	52.0	52.0	52.5	52.5	52.5
3	0	45.5	45.5	45.5	45.5	45.5	45.5	53.0	52.3	52.3	52.3	52.0	52.0	52.0	52.0	52.0	52.0	52.5	52.5	52.5
4	0	45.5	45.5	45.5	45.5	45.5	45.5	53.0	52.3	52.3	52.3	52.0	52.0	52.0	52.0	52.0	52.0	52.5	52.5	52.5
5	+2	43.5	43.5	43.5	43.5	43.5	43.5	51.0	50.3	50.3	51.0	50.0	50.0	50.0	50.0	50.0	50.0	50.5	50.5	50.5
6	+6	39.0	37.0	36.5	39.5	38.0	36.0	46.0	45.3	44.5	45.0	45.0	44.0	43.0	45.0	43.5	44.0	46.0	44.0	43.0
7	+9	30.0	20.5	20.0	34.0	26.0	18.0	39.0	33.5	30.0	30.0	37.0	28.0	22.0	34.0	23.0	22.0	38.0	27.0	21.0
8	+10	28.0	18.0	16.0	32.0	24.0	16.0	34.0	26.0	20.5	20.5	35.0	25.0	18.0	33.5	21.0	19.0	37.0	26.5	18.0
9	+10	26.0	13.0	10.5	32.0	22.0	12.0	29.0	18.0	8.0	8.0	34.0	21.0	11.0	31.5	16.0	13.0	36.0	24.0	14.0
10	+8.6	29.4	17.4	14.4	34.4	26.4	16.4	30.4	19.4	9.4	8.9	36.4	24.9	15.4	34.4	21.4	17.9	39.4	29.4	19.4
11	+5.72	32.3	20.3	13.3	37.3	29.3	15.3	33.3	22.3	10.3	8.3	39.3	28.2	15.3	37.3	25.3	18.3	42.3	33.3	20.3
12	+3.72	34.3	23.3	13.3	39.3	32.3	16.3	35.3	24.3	12.3	8.8	41.3	29.3	17.3	39.3	27.3	19.8	44.3	25.7	21.3
13	+0.75	37.75	28.25	14.25	42.75	36.25	18.25	38.25	27.25	18.25	8.75	44.25	34.25	22.25	43.25	33.25	25.25	48.25	41.25	26.25
14	-2	40.5	32.0	17.0	46.0	39.5	21.0	40.0	30.0	21.0	10.0	47.5	38.0	26.0	46.5	37.0	29.0	51.0	45.0	30.0
15	-4	44.0	37.0	24.5	48.0	43.0	28.0	44.0	34.0	27.0	17.0	50.5	43.0	33.0	50.0	43.0	37.0	54.0	49.0	37.0
16	-5	45.5	39.0	29.0	49.0	45.0	32.0	45.0	36.0	30.0	20.0	52.0	45.0	37.0	52.0	45.5	40.5	55.0	51.0	41.0
17	-5	46.5	40.5	33.0	49.0	45.0	35.0	46.0	38.0	33.0	25.0	53.0	46.5	40.0	53.0	47.0	43.0	55.5	52.0	44.0
18	-5	46.5	40.5	33.0	49.5	45.0	35.0	46.0	38.0	33.0	26.0	53.0	46.0	40.0	52.5	46.0	42.0	55.0	51.0	43.0
19	-5	45.0	39.5	30.0	49.0	45.5	34.0	46.0	38.0	32.0	26.0	51.5	45.0	37.0	51.0	45.0	40.0	54.5	50.0	40.0
20	-5	44.0	35.0	25.0	48.5	44.0	27.0	45.0	35.5	28.0	20.0	51.0	42.0	32.0	49.5	40.0	35.0	54.0	46.0	35.0
21	-5	44.0	36.0	26.0	48.5	42.5	26.0	45.0	36.0	29.0	21.0	51.0	42.0	33.0	49.5	41.0	36.0	54.0	47.0	36.0

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level. HW = headwater and G_o = gate opening.

Table 17

Pressures on Spillway Crest and Stilling Basin

Apron, High Gate Bays (Crest El +10.0; HW 60.0 and 65.0)

Piezometer		Pressure in Prototype Feet of Water													
		HW = 60.0, G_o = 20.17, Tailwater El			HW = 60.0, G_o = 24.75, Tailwater El		HW = 60.0, G_o = 28.83, Tailwater El		HW = 60.0, G_o = 36.19, Tailwater El		HW = 65.0, G_o = 20.17, Tailwater El		HW = 65.0, G_o = 24.75, Tailwater El	
No.	El	51.0	41.5	37.0	48.5	37.0	52.0	43.0	53.3	50.0	45.5	41.0	55.0	45.0
1	0	61.5	61.0	60.5	61.0	60.0	61.0	60.5	60.5	61.0	66.0	66.0	65.5	65.0
2	0	61.5	61.0	60.5	61.0	60.0	61.0	60.5	60.5	61.0	66.0	66.0	65.5	65.0
3	0	61.5	61.0	60.5	60.5	59.5	60.5	60.0	60.5	60.5	65.5	65.5	65.0	64.5
4	0	61.5	61.0	60.5	61.0	60.0	61.0	60.5	60.5	61.0	66.0	66.0	65.0	65.0
5	+2	59.5	59.0	58.5	59.0	58.0	59.0	58.5	58.5	59.0	64.5	64.5	63.0	63.0
6	+6	54.0	52.0	51.0	52.5	50.5	53.0	51.0	53.0	51.5	57.5	57.5	58.0	56.0
7	+9	43.0	33.0	27.0	37.0	24.0	39.5	25.0	36.5	28.0	37.0	32.0	44.0	30.0
8	+10	40.2	29.0	21.0	35.0	20.0	38.0	22.0	36.0	28.0	33.0	26.5	42.5	26.0
9	+10	37.5	22.0	12.0	31.5	12.5	35.5	26.0	34.5	25.0	27.0	18.0	39.5	20.0
10	+8.6	40.9	27.4	18.4	36.4	19.4	39.9	23.4	39.4	32.9	32.4	24.9	43.9	27.9
11	+5.72	43.3	29.3	19.3	38.8	19.8	43.2	27.8	43.8	37.8	33.8	26.3	46.8	30.8
12	+3.72	45.3	31.3	21.3	40.8	21.5	45.3	29.8	46.3	40.8	35.8	28.3	48.8	32.8
13	+0.75	49.25	35.25	28.25	45.25	28.8	49.3	36.7	50.25	47.3	40.25	34.25	53.25	38.75
14	-2	52.0	39.5	33.0	49.0	32.5	53.0	41.0	54.0	51.0	44.0	38.5	56.5	43.0
15	-4	56.0	45.5	40.0	53.5	41.0	56.5	47.5	58.5	56.0	50.0	45.0	60.0	50.0
16	-5	57.5	48.5	44.0	55.5	45.0	58.5	50.5	60.5	58.0	53.0	49.0	62.0	54.0
17	-5	59.0	50.5	47.0	57.0	48.0	59.5	52.5	61.0	59.0	55.5	52.0	63.5	55.5
18	-5	58.0	49.5	46.5	56.0	46.5	59.0	51.5	60.0	57.5	55.0	50.0	62.5	54.0
19	-5	57.5	48.0	43.0	54.5	43.0	58.0	49.0	60.0	56.5	51.5	48.0	62.0	51.5
20	-5	55.0	43.5	38.0	52.0	37.0	55.0	43.0	55.0	50.0	48.0	42.5	58.5	55.5
21	-5	55.0	44.5	39.0	52.0	38.0	55.5	45.0	57.0	53.0	47.5	43.5	58.5	56.5

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level.
HW = headwater and G_o= gate opening.

Table 18

Pressures on Spillway Crest and Stilling Basin

Apron, High Gate Bays (Crest El +10.0; HW 65.0 and 70.0)

Piezometer		Pressure in Prototype Feet of Water											
		HW = 65.0, G_o = 28.83, Tailwater El		HW = 65.0, G_o = 36.19, Tailwater El		HW = 70.0, G_o = 20.17, Tailwater El		HW = 70.0, G_o = 24.75, Tailwater El		HW = 70.0, G_o = 28.83, Tailwater El		HW = 70.0, G_o = 36.19, Tailwater El	
No.	El	54.0	46.0	58.0	51.5	51.0	43.0	50.0	44.5	58.5	48.5	61.0	54.5
1	0	66.0	65.0	66.0	65.0	71.0	71.0	71.0	71.0	71.0	71.0	70.5	70.0
2	0	66.0	65.0	66.0	65.0	71.0	71.0	71.0	71.0	71.0	71.0	70.5	70.0
3	0	65.5	65.0	66.0	65.0	70.5	70.5	70.5	70.5	70.5	70.5	70.5	69.5
4	0	66.0	65.0	66.5	66.0	71.0	71.0	71.0	71.0	71.0	71.0	71.0	70.0
5	+2	64.0	63.0	64.5	64.0	69.0	69.0	69.0	69.0	69.0	69.0	69.5	68.5
6	+6	57.5	55.0	58.0	56.0	63.0	62.0	61.0	60.0	62.0	60.0	63.0	60.0
7	+9	41.0	27.0	42.0	26.0	44.0	36.0	36.0	28.0	46.5	30.0	45.0	27.0
8	+10	39.5	24.5	41.5	26.0	40.0	28.5	33.0	23.0	45.0	27.0	45.0	27.0
9	+10	37.0	19.0	40.0	22.5	33.5	20.0	27.5	24.5	42.0	21.0	42.0	23.0
10	+8.6	41.4	26.9	44.9	31.4	38.9	25.4	34.4	23.4	47.4	28.4	47.9	32.9
11	+5.72	44.8	30.3	48.8	37.3	41.3	28.3	36.8	25.3	50.3	32.3	51.8	38.8
12	+3.72	46.8	32.8	51.3	40.3	43.3	30.3	38.8	27.8	52.3	34.8	54.3	41.3
13	+0.75	51.3	40.3	55.8	47.8	47.3	35.3	44.3	35.3	56.8	42.3	59.3	49.3
14	-2	55.0	44.5	59.5	52.0	51.0	39.0	48.0	40.0	61.0	46.0	63.0	54.5
15	-4	59.5	51.0	63.5	57.0	57.0	47.0	55.0	49.0	65.0	53.5	67.0	60.5
16	-5	62.0	54.0	65.0	60.0	59.5	51.0	58.0	53.0	67.0	57.0	69.0	63.0
17	-5	63.0	56.0	65.5	61.0	61.5	54.0	60.5	56.0	67.5	60.0	69.5	64.0
18	-5	62.0	55.0	63.5	59.5	61.0	53.0	59.5	54.0	67.0	57.5	68.5	62.0
19	-5	60.5	52.0	64.0	58.5	57.0	50.5	57.0	50.0	66.0	55.0	67.5	61.5
20	-5	57.0	56.0	60.5	50.5	54.0	44.0	51.0	42.5	62.5	47.5	63.0	52.0
21	-5	56.5	57.0	61.0	53.5	53.5	45.0	52.0	45.0	62.5	49.0	64.0	55.0

Note: Piezometer locations are shown in Plate 4. Elevations are in feet referred to mean sea level.
HW = headwater and G_o = gate opening.

Table 19

Forces on Vertical-Lift Gates

Low Gate Bay, No. 6 (Crest El -5.0)

Test Conditions				Static Load			Dynamic Load*		
Pool El	Tailwater El	Gate Opening ft	No. of Gate Leaves	Maximum Uplift kips	Maximum Downpull kips	Fluctuation kips	Maximum Uplift kips	Maximum Downpull kips	Fluctuation kips
54.7	46.3	28.83	3	12	--	5	--	46	23
54.3	47.1	43.4	2	--	34	9	--	73	37
51.5	45.2	24.75	3	9	--	3	--	--	--
51.0	47.0	47.02	3	9	8	17	--	--	--

Note: Elevations are in feet referred to mean sea level.
Dead weight of gate leaves.
(3) Leaves = 285 kips
(2) Leaves = 194 kips

* Gates leaves were moving upward.

Table 20

Horizontal Forces on Gate Leaves, Crest El -5.0

Gate Opening ft	Headwater Elevation ft	Tailwater Elevation ft	Average Velocity fps	Actual Tail-water Elevation on Back of Gate, ft	Static Force on Front of Gate kips	Static Force on Front of Gate Acting at El	Force of Velocity Head on Gate kips	Force of Velocity Head on Gate Acting at El	Static Force on Back of Gate kips	Static Force on Back of Gate Acting at El	Total Force on Gate kips	Total Force on Gate Acting at El
4.0	30.0	15.0	4.6	14.40	1319.26	9.3	13.98	15.2	325.57	4.1	1007.67	11.1
4.0	30.0	10.5	5.6	8.10	1319.26	9.3	20.35	14.8	113.68	2.0	1225.93	10.1
4.0	30.0	5.0	5.1	0.00	1319.26	9.3	16.85	13.6	0.00	0.0	1336.11	9.4
4.0	30.0	1.0	5.1	0.00	1319.26	9.3	17.19	13.5	0.00	0.0	1336.45	9.4
11.3	30.0	22.5	6.4	20.10	774.35	14.2	20.74	17.7	263.33	10.9	531.75	15.9
11.3	30.0	16.9	8.2	12.50	774.35	14.2	33.63	17.7	53.63	8.3	754.35	14.7
11.3	30.0	14.0	9.0	7.00	774.35	14.2	40.74	17.6	0.77	6.5	814.31	14.3
11.3	30.0	5.8	9.8	0.00	774.35	14.2	48.62	17.8	0.00	0.0	822.97	14.4
20.2	30.0	28.0	2.0	27.12	301.92	20.1	1.26	25.1	196.04	19.2	107.14	21.9
20.2	30.0	24.0	5.2	20.18	301.92	20.1	8.55	25.1	34.46	16.8	276.01	20.7
20.2	30.0	20.0	10.3	0.00	301.92	20.1	33.54	25.1	0.00	0.0	335.46	20.6
20.2	30.0	15.8	11.6	0.00	301.92	20.1	42.54	25.1	0.00	0.0	334.46	20.7
20.2	30.0	11.8	12.3	0.00	301.92	20.1	47.83	25.1	0.00	0.0	349.75	20.8
24.8	30.0	24.8	9.6	22.08	144.23	23.2	20.14	27.4	7.45	20.5	156.91	23.8
24.8	30.0	20.0	13.8	0.00	144.23	23.2	41.61	27.4	0.00	0.0	185.84	24.1
24.8	30.0	14.0	15.3	0.00	144.23	23.2	51.15	27.4	0.00	0.0	195.38	24.3
4.0	40.0	35.0	0.8	39.96	2307.68	12.7	0.49	16.0	2303.18	12.7	4.99	19.1
4.0	40.0	28.5	1.6	27.40	2307.68	12.7	2.24	15.6	1107.25	8.5	1202.67	16.5
4.0	40.0	23.2	2.9	23.10	2307.68	12.7	7.10	16.0	797.34	7.0	1517.44	15.6
4.0	40.0	20.0	2.9	18.40	2307.68	12.7	7.35	16.2	516.67	5.5	1798.36	14.7
4.0	40.0	14.0	3.2	12.00	2307.68	12.7	8.67	16.0	232.00	3.3	2084.35	13.7
4.0	40.0	7.0	3.6	0.00	2307.68	12.7	11.33	14.8	0.00	0.0	2319.00	12.7
11.3	40.0	36.0	1.8	36.40	1563.71	17.5	2.20	20.2	1247.91	16.3	318.00	22.2
11.3	40.0	26.5	4.8	23.10	1563.71	17.5	16.58	19.1	389.77	11.9	1190.51	19.4
11.3	40.0	21.2	5.7	26.50	1563.71	17.5	22.97	19.7	147.06	9.7	1439.61	18.3
11.3	40.0	15.0	7.5	0.00	1563.71	17.5	39.93	20.1	0.00	0.0	1603.64	17.6
11.3	40.0	8.0	7.6	0.00	1563.71	17.5	41.01	20.3	0.00	0.0	1604.71	17.6
20.2	40.0	37.0	7.1	35.68	846.37	23.4	26.31	27.0	577.48	22.0	295.20	26.6
20.2	40.0	33.0	8.1	29.60	846.37	23.4	34.73	27.1	285.85	20.0	595.25	25.3
20.2	40.0	28.5	10.1	23.80	846.37	23.4	53.46	27.1	102.24	18.0	797.59	24.4
20.2	40.0	23.5	11.7	0.00	846.37	23.4	72.46	26.6	0.00	0.0	918.83	23.7
20.2	40.0	15.0	11.8	0.00	846.37	23.4	73.08	26.3	0.00	0.0	919.45	23.7
20.2	40.0	14.0	12.6	0.00	846.37	23.4	84.03	26.5	0.00	0.0	930.40	23.7
24.8	40.0	34.0	7.0	0.00	562.93	26.5	21.15	28.6	0.00	0.0	584.09	26.6
24.8	40.0	26.0	8.8	0.00	562.93	26.5	33.05	28.2	0.00	0.0	595.98	26.6
24.8	40.0	23.0	10.4	0.00	562.93	26.5	46.69	28.5	0.00	0.0	609.62	26.7
24.8	40.0	19.0	10.4	0.00	562.93	26.5	46.69	28.5	0.00	0.0	609.62	26.7
24.8	40.0	17.5	10.8	0.00	562.93	26.5	50.35	28.4	0.00	0.0	613.28	26.7
28.8	40.0	35.5	7.6	0.00	358.94	29.2	20.01	34.4	0.00	0.0	378.96	29.5
28.8	40.0	31.0	10.7	0.00	358.94	29.2	39.46	34.4	0.00	0.0	398.41	29.7
28.8	40.0	24.0	14.0	0.00	358.94	29.2	67.56	34.4	0.00	0.0	426.50	30.0
28.8	40.0	20.5	13.2	0.00	358.94	29.2	60.06	34.4	0.00	0.0	419.00	30.0
4.0	52.0	48.0	0.5	49.12	3856.20	16.7	0.28	9.0	3448.49	15.7	407.98	24.8
4.0	52.0	40.0	1.3	39.76	3856.20	16.7	1.77	15.6	2280.74	12.6	1577.22	22.6
4.0	52.0	34.5	2.5	34.00	3856.20	16.7	7.06	15.6	1681.68	10.7	2181.58	21.3
4.0	52.0	28.5	3.0	27.50	3856.20	16.7	10.17	18.9	1115.06	8.5	2751.31	20.0
4.0	52.0	20.5	3.9	18.50	3856.20	16.7	16.75	19.7	522.01	5.5	3350.93	18.4
4.0	52.0	12.0	3.9	5.20	3856.20	16.7	16.75	19.7	52.77	1.1	3820.17	16.9
4.0	52.0	8.5	3.9	0.00	3856.20	16.7	16.75	19.7	0.00	0.0	3872.94	16.7
4.0	52.0	2.0	3.9	0.00	3856.20	16.7	16.75	19.7	0.00	0.0	3872.94	16.7
11.3	52.0	48.5	1.8	47.68	2873.36	21.5	3.16	20.5	2356.34	20.1	520.18	28.0
11.3	52.0	43.0	2.4	42.28	2873.36	21.5	5.62	19.5	1782.12	18.3	1096.86	26.8
11.3	52.0	36.0	4.3	34.00	2873.36	21.5	18.03	19.2	1057.14	15.5	1834.25	24.9
11.3	52.0	24.0	5.9	17.80	2873.36	21.5	33.60	18.4	183.13	10.1	2723.83	22.2
11.3	52.0	19.0	6.6	0.00	2873.36	21.5	42.93	18.2	0.00	0.0	2916.29	21.5
11.3	52.0	16.0	6.6	0.00	2873.36	21.5	43.13	18.2	0.00	0.0	2916.48	21.5
11.3	52.0	12.0	6.6	0.00	2873.36	21.5	43.13	18.2	0.00	0.0	2916.48	21.5
11.3	52.0	8.0	6.6	0.00	2873.36	21.5	43.13	18.2	0.00	0.0	2916.48	21.5
20.2	52.0	49.0	2.9	47.68	1862.13	27.4	6.38	26.6	1450.91	26.0	417.60	32.4
20.2	52.0	42.5	4.3	40.50	1862.13	27.4	14.18	27.0	880.80	23.6	995.51	30.8

(Continued)

Note: Elevations are in feet referred to mean sea level.

Table 20 (Concluded)

Gate Opening ft	Headwater Elevation ft	Tailwater Elevation ft	Average Velocity fps	Actual Tail-water Elevation on Back of Gate, ft	Static Force on Front of Gate		Force of Velocity Head on Gate		Static Force on Back of Gate		Total Force on Gate	
					kips	Acting at El	kips	Acting at El	kips	Acting at El	kips	Acting at El
20.2	52.0	36.5	5.9	30.40	1862.13	27.4	27.05	26.6	318.42	20.2	1570.76	28.9
20.2	52.0	29.0	7.1	0.00	1862.13	27.4	39.58	26.4	0.00	0.0	1901.71	27.4
20.2	52.0	25.0	8.1	0.00	1862.13	27.4	52.15	26.2	0.00	0.0	1914.28	27.4
20.2	52.0	13.0	8.6	0.00	1862.13	27.4	58.74	27.1	0.00	0.0	1920.88	27.4
24.8	52.0	48.0	4.4	44.80	1427.80	30.5	13.61	33.9	861.44	28.1	579.98	34.1
24.8	52.0	43.0	4.8	39.40	1427.80	30.5	15.51	33.6	530.07	26.3	913.24	33.0
24.8	52.0	38.0	6.8	34.00	1427.80	30.5	31.79	32.8	278.76	24.5	1180.82	32.0
24.8	52.0	35.0	7.6	28.50	1427.80	30.5	39.71	33.1	105.11	22.7	1362.40	31.2
24.8	52.0	28.5	8.4	0.00	1427.80	30.5	47.93	33.0	0.00	0.0	1475.73	30.6
24.8	52.0	23.5	9.6	0.00	1427.80	30.5	63.36	33.6	0.00	0.0	1491.15	30.6
24.8	52.0	15.0	10.0	0.00	1427.80	30.5	68.06	33.5	0.00	0.0	1495.86	30.6
28.8	52.0	48.0	5.1	45.12	1089.38	33.2	15.31	37.2	622.24	30.9	482.46	36.3
28.8	52.0	44.0	6.5	40.12	1089.38	33.2	25.37	36.6	364.29	29.3	750.46	35.3
28.8	52.0	40.0	7.1	34.00	1089.38	33.2	30.27	36.9	141.99	27.2	977.67	34.2
28.8	52.0	36.0	8.4	0.00	1089.38	33.2	42.37	36.0	0.00	0.0	1131.75	33.3
28.8	52.0	33.5	10.0	0.00	1089.38	33.2	60.05	36.6	0.00	0.0	1149.43	33.4
28.8	52.0	30.0	10.8	0.00	1089.38	33.2	70.04	36.7	0.00	0.0	1159.43	33.4
28.8	52.0	26.0	11.4	0.00	1089.38	33.2	78.04	36.6	0.00	0.0	1167.42	33.4
28.8	52.0	18.0	11.4	0.00	1089.38	33.2	78.04	36.6	0.00	0.0	1167.42	33.4

Table 21

Horizontal Forces on Gate Leaves, Crest El +10.0

Gate Opening ft	Headwater Elevation ft	Tailwater Elevation ft	Average Velocity fps	Actual Tail-water Elevation on Back of Gate, ft	Static Force on Front of Gate kips	Static Force on Front of Gate Acting at El	Force of Velocity Head on Gate kips	Force of Velocity Head on Gate Acting at El	Static Force on Back of Gate kips	Static Force on Back of Gate Acting at El	Total Force on Gate kips	Total Force on Gate Acting at El
6.0	30.0	15.0	4.8	0.00	269.07	20.7	6.88	23.0	0.00	0.0	275.94	20.7
6.0	30.0	20.0	4.0	0.00	269.07	20.7	4.77	23.0	0.00	0.0	273.84	20.7
6.0	30.0	24.0	3.4	22.20	269.07	20.7	3.45	23.0	52.77	18.1	219.75	21.3
6.0	30.0	28.0	3.0	27.50	269.07	20.7	2.69	23.0	181.55	19.8	90.20	22.4
11.3	30.0	15.0	8.4	0.00	105.11	24.2	13.16	25.9	0.00	0.0	118.27	24.4
11.3	30.0	19.5	8.3	0.00	105.11	24.2	12.85	25.9	0.00	0.0	117.95	24.4
11.3	30.0	23.0	7.6	0.00	105.11	24.2	10.77	25.9	0.00	0.0	115.88	24.3
11.3	30.0	25.0	6.8	0.00	105.11	24.2	8.62	25.9	0.00	0.0	113.73	24.3
11.3	30.0	27.0	4.8	26.43	105.35	24.2	4.30	25.9	36.98	23.0	72.67	24.9
11.3	30.0	29.0	4.8	28.95	105.11	24.2	4.30	25.9	81.39	23.8	28.01	25.4
11.3	40.0	11.0	6.6	0.00	482.63	27.5	17.68	29.8	0.00	0.0	500.30	27.6
11.3	40.0	16.0	6.2	0.00	482.63	27.5	15.36	29.9	0.00	0.0	497.99	27.6
11.3	40.0	19.0	6.2	0.00	482.63	27.5	15.36	29.9	0.00	0.0	497.99	27.6
11.3	40.0	24.5	6.2	0.00	482.63	27.5	15.36	29.9	0.00	0.0	497.99	27.6
11.3	40.0	28.0	5.8	0.00	482.63	27.5	13.45	30.2	0.00	0.0	496.07	27.6
11.3	40.0	31.5	5.3	29.55	482.63	27.5	11.23	30.5	94.57	24.0	399.28	28.4
11.3	40.0	37.5	4.1	37.15	482.63	27.5	6.72	30.2	347.06	26.5	142.29	29.9
20.2	40.0	27.0	9.6	0.00	132.65	33.4	19.31	35.6	0.00	0.0	151.96	33.7
20.2	40.0	33.0	8.4	0.00	132.65	33.4	14.79	35.6	0.00	0.0	147.44	33.7
20.2	40.0	34.5	7.6	0.00	132.65	33.4	12.10	35.6	0.00	0.0	144.76	33.6
20.2	40.0	36.3	6.8	33.77	132.65	33.4	9.69	35.6	17.79	31.4	124.55	33.9
20.2	40.0	38.0	4.8	36.27	132.65	33.4	4.83	35.6	51.08	32.2	86.40	34.3
11.3	52.0	27.0	5.9	0.00	1298.07	31.5	22.82	34.7	0.00	0.0	1320.89	31.6
11.3	52.0	32.0	5.5	26.45	1298.07	31.5	19.83	34.9	37.12	23.0	1280.78	31.8
11.3	52.0	34.5	5.1	30.75	1298.07	31.5	16.72	35.1	123.90	24.4	1190.89	32.3
11.3	52.0	40.5	3.9	38.75	1298.07	31.5	9.72	34.1	420.42	27.1	887.36	33.6
11.3	52.0	46.0	2.8	46.25	1298.07	31.5	4.96	33.6	858.00	29.6	445.03	35.2
20.2	52.0	35.0	7.5	0.00	654.21	37.4	26.18	39.6	0.00	0.0	680.38	37.5
20.2	52.0	38.5	6.2	0.00	654.21	37.4	17.89	39.1	0.00	0.0	672.09	37.5
20.2	52.0	42.5	4.4	35.87	654.21	37.4	9.01	38.6	44.60	32.1	618.61	37.9
20.2	52.0	46.0	3.1	45.27	654.21	37.4	4.47	37.9	313.01	35.2	345.67	39.5
20.2	52.0	48.5	2.4	47.77	654.21	37.4	2.68	36.2	425.24	36.0	231.65	40.0
24.8	52.0	38.2	9.3	0.00	408.49	40.5	31.60	42.7	0.00	0.0	440.09	40.7
24.8	52.0	43.0	8.2	36.95	408.49	40.5	24.73	42.8	6.64	35.5	426.57	40.7
28.8	52.0	38.5	11.3	0.00	238.11	43.2	35.53	45.3	0.00	0.0	273.64	43.5
28.8	52.0	44.0	10.2	0.00	238.11	43.2	28.92	45.3	0.00	0.0	267.03	43.4
24.8	52.0	46.0	6.4	43.35	408.49	40.5	15.06	42.5	101.53	37.6	322.02	41.5
24.8	52.0	48.0	5.2	46.73	408.49	40.5	9.94	42.1	197.02	38.7	221.41	42.1
28.8	52.0	47.0	8.0	43.51	238.11	43.2	17.97	45.3	30.07	40.4	226.01	43.8
28.8	52.0	49.0	6.4	46.73	238.11	43.2	11.32	45.3	85.68	41.5	163.75	44.3

Note: Elevations are in feet referred to mean sea level.

Table 22

Velocities for Low Gate Bays (Crest El -5.0), Uncontrolled Flow

HW = 30.0 ft			HW = 40.0 ft			HW = 52.0 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
29.5	9.6	7.6	38.5	17.3	16.2	49.0	19.3	16.2
28.0	15.2	13.6	35.0	22.6	19.2	46.5	24.5	21.0
26.0	18.3	17.1	33.5	23.1	20.0	43.5	26.1	28.5
23.5	19.3	19.6	32.0	23.1	24.1	41.0	29.6	32.6
21.0	20.4	22.3	28.0	24.0	29.6	29.5	29.6	36.6
17.0	21.0	24.1	24.0	25.5	32.7	--	--	--

Note: Upstream velocities measured at sta 99+38.17 and 10 ft above channel bottom. Downstream velocities measured 100 ft below end sill and 10 ft above channel bottom. Elevations are in feet referred to mean sea level.

Table 23

Velocities for High Gate Bays (Crest El +10.0),

Uncontrolled Flow

HW = 30.0 ft			HW = 40.0 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
4.5	8.3	28.5	10.8	13.6	32.5
14.0	8.3	22.5	26.5	13.6	21.5
17.0	8.3	16.2	30.5	12.7	16.5
20.0	8.3	12.3	33.0	12.7	15.5
23.0	9.0	10.7	35.0	12.7	14.4
25.5	8.3	9.7	37.0	11.8	13.8
27.0	8.3	9.6	38.5	11.8	12.7
29.0	6.7	8.3	39.2	9.6	11.8

HW = 45.0 ft			HW = 55.0 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
14.5	14.4	33.0	24.0	20.4	31.5
32.0	14.4	22.5	39.0	18.0	24.5
35.0	14.4	18.0	43.0	17.2	23.1
37.5	13.6	14.5	47.0	17.2	20.1
39.0	12.7	13.7	49.5	15.9	18.6
41.5	11.8	13.2	52.0	15.3	18.0
43.0	10.7	11.6	53.0	13.8	15.2
			43.0	10.8	13.2

Note: Upstream velocities measured at sta 99+38.17. Downstream velocities measured 100 ft below end sill. All velocities measured 10 ft above channel bottom. Elevations are in feet referred to mean sea level.

Table 24

Velocities for Low Gate Bays with Gate Leaf 4L Installed On Crest

(Weir El +10.0), Uncontrolled Weir Flow

HW = 15.0 ft			HW = 20.0 ft			HW = 25.0 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
14.0	4.0	0.5	19.5	6.0	1.0	24.0	7.2	3.1
12.0	4.0	1.0	18.0	6.0	2.5	20.0	7.2	4.6
10.0	4.4	2.1	15.0	6.0	4.2	17.5	7.2	6.1
7.0	4.5	3.5	12.0	6.0	5.3	13.0	7.6	8.0
3.0	4.5	4.6	9.0	6.1	7.6	8.0	7.6	11.8
1.0	4.5	7.6*	4.0	6.1	9.7	4.0	7.6	13.8
-2.0	4.5	9.6*	1.0	6.1	12.3*	--	--	--

Note: Upstream velocities measured at sta 99+38.17 and 16 ft above channel bottom. Downstream velocities measured 100 ft below and 10 ft above channel bottom. Elevations are in feet referred to mean sea level.

* Velocities measured on the channel bottom.

Table 25

Velocities for Low Gate Bays with Gate Leaves (4L and 3L) Installed on Crest

(Weir El +29.0), Uncontrolled Weir Flow

HW = 32.0 ft			HW = 37.0 ft			HW = 42.0 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
29.5	0.5	1.0	31.0	4.0	2.0	37.0	4.0	2.0
25.0	0.5	1.0	29.0	4.0	2.2	33.5	4.2	2.5
17.0	0.5	2.0	23.0	4.0	3.0	28.0	4.2	4.0
14.0	0.5	2.5	15.0	4.2	4.2	21.0	4.2	5.9
11.0	1.0	2.5	12.0	4.2	5.9	13.0	4.2	8.4
6.0	1.0	2.5	5.5	4.2	7.6	5.0	4.2	12.3**
3.5	2.0	3.0*	8.5	4.2	5.0	3.0	4.2	16.1**
2.0	2.0	4.0*	3.0	4.2	9.3*	--	--	--
-3.0	2.0	8.6*	0.0	4.2	12.6*	--	--	--

Note: Upstream velocities measured at sta 99+38.17 and 35 ft above channel bottom. Downstream velocities measured 100 ft below and 10 ft above channel bottom. Elevations are in feet referred to mean sea level.

* Velocities measured on the channel bottom.

** Velocities measured 5 ft above channel bottom.

Table 26

Velocities for Low Gate Bays (Crest El -5.0), Controlled Flow

HW = 30.0 ft, G_o = 4.0 ft			HW = 30.0 ft, G_o = 11.25 ft			HW = 30.0 ft, G_o = 20.17 ft			HW = 30.0 ft, G_o = 24.75 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
1.0	5.0	11.2	5.8	9.0	15.8	11.8	14.5	22.6	14.0	17.0	23.6
5.0	5.0	9.7	14.0	9.0	12.0	15.8	14.6	18.1	20.0	16.2	19.2
10.5	4.8	4.8	16.9	8.2	9.3	20.0	12.3	13.8	24.8	11.8	11.4
15.0	4.8	4.2	22.5	6.8	5.0	24.0	10.2	9.3	--	--	--
19.3	2.3	3.0	28.0	3.4	3.0	28.0	6.8	4.2	--	--	--
24.0	2.3	1.5									
28.0	2.3	1.0									

HW = 40.0 ft, G_o = 4.0 ft			HW = 40.0 ft, G_o = 11.25 ft			HW = 40.0 ft, G_o = 20.17 ft			HW = 40.0 ft, G_o = 24.75 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
1.5	5.8	12.3	8.0	10.2	19.7	14.0	10.7	22.1	17.5	7.6	24.8
7.0	5.8	7.6	15.0	9.6	13.8	15.0	10.7	21.0	19.0	7.6	22.3
14.0	5.0	6.0	21.2	8.3	7.6	23.5	10.2	15.2	23.0	7.6	20.1
20.0	4.9	4.7	26.5	6.8	5.9	28.5	9.4	9.7	26.0	5.9	17.0
23.2	4.9	4.2	36.0	4.8	4.2	33.0	7.6	5.9	34.0	5.2	8.8
28.5	4.6	3.7	--	--	--	37.0	6.5	4.2	--	--	--
35.0	3.4	2.0									

(Continued)

Note: Upstream velocities measured at sta 99+38.17 and 10 ft above channel bottom. Flevations are in feet referred to mean sea level.

(Sheet 1 of 3)

Table 26 (Continued)

HW = 40.0 ft, G_o = 28.83 ft			HW = 52.0 ft, G_o = 4.0 ft			HW = 52.0 ft, G_o = 11.25 ft			HW = 52.0 ft, G_o = 20.17 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
20.5	17.3	26.3	2.0	4.8	14.5	8.0	9.0	21.5	13.0	14.5	31.3
24.0	16.7	21.0	8.5	4.8	10.2	12.0	9.0	19.0	22.0	13.6	18.7
31.0	13.6	13.9	12.0	4.8	7.6	16.0	9.0	13.8	25.0	13.2	16.2
35.5	9.0	8.7	20.5	4.8	5.4	19.0	8.8	13.2	29.0	11.8	14.4
--	--	--	28.5	4.4	4.2	24.0	8.5	8.7	36.5	9.6	7.9
--	--	--	34.5	3.8	3.4	36.0	5.2	4.6	42.5	8.3	4.6
			40.0	3.4	3.0	43.0	4.8	3.8	49.0	5.9	3.5
			48.0	2.0	1.5	48.5	3.4	3.0	--	--	--

HW = 52.0 ft, G_o = 24.75 ft			HW = 52.0 ft, G_o = 28.83 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
15.0	14.5	33.0	18.0	16.7	33.7
23.5	14.5	25.0	26.0	16.1	28.0
28.5	14.0	17.0	30.0	15.9	21.1
35.0	12.3	9.5	33.5	14.5	17.1
38.0	10.7	7.5	36.0	13.6	13.2
43.0	9.6	5.2	40.0	11.8	8.8
48.0	6.8	4.0	44.0	10.7	5.2
			48.0	8.3	4.2

(Continued)

Table 26 (Concluded)

HW = 52.0 ft, G_o = 36.19 ft		HW = 52.0 ft, G_o = 43.53 ft		HW = 60.0 ft, G_o = 20.17 ft		HW = 60.0 ft, G_o = 24.75 ft		HW = 60.0 ft, G_o = 28.83 ft		HW = 60.0 ft, G_o = 36.19 ft	
Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps
16.5	36.0	20.0	32.6	8.0	31.0	10.0	37.2	12.0	27.2	16.0	29.6
30.0	24.0	36.0	25.5	26.0	15.2	28.0	21.5	30.0	23.0	35.0	24.0
33.5	22.0	39.0	22.5	31.0	11.8	32.0	19.2	32.0	21.5	37.0	21.0
37.0	19.2	41.0	20.4	33.5	9.6	35.0	15.2	36.5	18.0	40.0	18.6
40.0	15.9	43.5	17.3	38.8	4.8	37.0	10.7	38.5	14.4	44.0	12.7
42.0	11.8	45.0	15.2	47.0	4.3	41.7	6.8	42.8	8.3	46.0	11.8
44.8	6.8	47.0	10.7	50.0	3.6	48.0	4.8	48.0	4.8	48.8	6.8
47.5	4.8	48.0	8.3	55.0	2.6	51.5	3.6	54.5	3.6	51.5	4.8
51.0	3.4	49.5	6.8			57.5	2.2	58.0	2.6	57.0	3.4

HW = 60.0 ft, G_o = 43.53 ft		HW = 65.0 ft, G_o = 20.17 ft		HW = 65.0 ft, G_o = 24.75 ft		HW = 65.0 ft, G_o = 28.83 ft		HW = 65.0 ft, G_o = 36.19 ft		HW = 65.0 ft, G_o = 43.53 ft	
Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps
20.0	31.0	8.0	27.2	10.0	33.0	12.0	31.5	16.0	26.0	21.0	34.0
41.0	24.5	28.5	15.2	30.0	21.5	32.0	23.5	37.0	22.5	45.0	20.0
44.0	19.8	34.0	9.6	33.0	18.0	33.0	21.0	40.5	20.0	48.0	16.6
49.5	15.2	37.0	6.8	35.0	16.7	38.0	17.3	42.5	18.0	50.0	15.9
50.5	11.8	45.5	4.8	40.0	9.6	41.0	13.6	44.5	16.6	52.5	10.8
53.5	6.8	51.0	3.7	44.5	6.8	44.5	7.8	49.0	11.8	55.0	8.3
55.0	5.9	54.0	2.6	48.5	4.8	52.0	4.8	51.0	8.3	57.0	4.8
56.8	4.8	59.5	2.2	56.5	3.6	58.5	4.3	57.0	4.8	59.0	4.3
58.8	3.2			62.0	2.0	61.5	3.4	62.0	3.4	61.0	3.4

Note: Downstream velocities measured 100 ft below and 10 ft above end sill.

Table 27

Velocities for High Gate Bays (Crest El +10.0), Controlled Flow

HW = 30.0 ft, G_o = 6.0 ft			HW = 30.0 ft, G_o = 11.25 ft			HW = 40.0 ft, G_o = 6.0 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
0.5	4.6	18.0	3.0	--	24.6	1.0	4.8	19.5
11.0	4.6	10.7	12.0	--	19.2	4.0	4.8	18.5
15.0	4.6	7.6	15.0	--	15.6	11.5	4.8	12.3
20.0	4.6	5.8	19.5	--	10.7	16.0	4.8	7.6
24.0	4.6	4.6	23.0	--	8.6	21.0	4.8	5.9
28.0	3.4	2.0	25.0	--	6.8	25.0	4.8	4.2
			27.0	--	4.5	30.0	4.8	4.2
			29.0	--	2.6	35.0	3.4	3.2

HW = 40.0 ft, G_o = 11.25 ft			HW = 40.0 ft, G_o = 20.17 ft			HW = 45.0 ft, G_o = 11.25 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
5.0	--	24.6	9.0	11.28	29.3	6.0	6.8	24.0
11.0	--	23.4	23.0	11.28	15.3	14.0	6.8	22.1
16.0	--	19.0	27.0	11.28	13.8	17.0	6.8	20.1
19.0	--	13.5	33.0	10.74	10.7	21.0	6.8	14.2
24.5	--	9.7	34.5	9.6	7.6	27.0	6.8	8.6
28.0	--	6.8	36.3	6.8	5.8	30.5	6.8	5.9
31.5	--	3.8	38.0	4.8	2.2	35.0	4.8	3.6
37.5	--	2.1				40.0	4.8	2.2

(Continued)

Note: Upstream velocities measured at sta 99+43.17 and 15 ft above channel bottom. Downstream velocities measured 100 ft below and 10 ft above end sill. Elevations are in feet referred to mean sea level

Table 27 (Continued)

HW = 45.0 ft, G_o = 20.17 ft			HW = 45.0 ft, G_o = 24.75 ft			HW = 52.0 ft, G_o = 11.25 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
10.0	10.75	30.8	11.5	10.74	31.0	6.5	7.0	27.3
16.0	10.75	24.0	23.0	10.74	27.0	18.0	7.0	20.1
23.0	10.75	20.0	27.0	10.74	23.1	21.0	7.0	16.2
27.0	10.75	14.2	35.0	10.74	13.8	25.0	7.0	10.8
33.0	10.75	12.4	39.0	9.6	10.74	27.0	7.0	7.6
36.0	9.6	8.7	42.0	8.4	5.9	32.0	6.8	7.2
39.5	6.8	3.6	43.5	4.8	4.2	34.5	6.8	6.0
43.0	4.8	2.6	44.5	4.8	3.4	40.5	6.8	3.6
						46.0	5.9	1.5

HW = 52.0 ft, G_o = 20.17 ft			HW = 52.0 ft, G_o = 24.75 ft			HW = 52.0 ft, G_o = 28.83 ft		
Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps	Tailwater El	Velocity Upstream fps	Velocity Downstream fps
11.0	10.74	31.6	13.0	11.8	35.4	15.0	14.46	36.9
27.0	10.74	19.3	28.5	11.8	27.5	32.0	14.46	35.1
31.0	10.74	13.6	33.5	11.8	17.3	35.0	14.46	21.0
35.0	10.74	12.7	36.5	11.8	15.3	38.5	14.46	17.0
38.5	9.6	8.7	38.5	11.8	13.6	44.0	12.3	13.2
42.5	8.4	4.3	43.0	9.6	8.8	47.0	9.6	6.8
46.0	6.8	2.0	46.0	9.0	6.0	49.0	6.8	4.0
48.5	4.8	1.0	48.0	5.9	3.4			

(Continued)

Table 27 (Continued)

HW = 60.0 ft, G_o = 11.25 ft		HW = 60.0 ft, G_o = 20.17 ft		HW = 60.0 ft, G_o = 24.75 ft		HW = 60.0 ft, G_o = 28.83 ft	
Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps
7.0	24.5	12.0	34.7	14.0	38.8	15.5	36.6
20.5	16.6	33.5	15.2	35.0	20.4	36.5	22.0
24.0	15.2	37.0	13.6	37.0	18.6	38.5	19.2
27.5	12.7	40.0	11.5	44.5	13.6	43.0	18.0
29.5	10.7	41.5	10.1	46.0	9.6	46.0	15.2
32.0	9.0	44.0	7.6	48.5	6.8	49.5	8.3
35.5	8.3	47.0	5.9	52.0	5.5	52.0	5.9
41.0	5.9	51.0	4.8	55.0	4.3	56.0	4.8
44.5	4.8	55.5	3.4			59.0	3.4
49.0	3.4						

HW = 60.0 ft, G_o = 36.19 ft		HW = 65.0 ft, G_o = 11.25 ft		HW = 65.0 ft, G_o = 20.17 ft		HW = 65.0 ft, G_o = 24.75 ft	
Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps
19.0	36.8	7.0	25.5	12.0	38.7	35.0	27.6
42.0	23.0	23.0	16.6	32.0	21.5	37.5	20.4
46.5	19.8	26.0	14.4	35.0	15.2	42.0	17.3
50.0	18.0	27.5	13.6	41.0	13.6	45.0	13.6
52.0	15.2	32.0	10.7	43.0	10.8	47.5	11.3
53.5	12.7	35.0	8.3	45.5	7.6	50.5	7.1
55.5	9.6	39.0	6.8	48.0	5.0	55.0	5.0
59.0	4.8	44.0	4.8	54.5	4.8	60.5	3.0
		50.5	3.4	59.0	2.4		

(Continued)

Table 27 (Concluded)

HW = 65.0 ft, G_o = 28.83 ft		HW = 65.0 ft, G_o = 36.19 ft		HW = 70.0 ft, G_o = 11.25 ft		HW = 70.0 ft, G_o = 20.17 ft	
Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps
15.0	36.0	20.0	38.4	7.0	30.4	12.0	32.0
38.0	27.0	46.0	21.5	25.0	15.2	38.5	15.2
40.0	19.8	48.5	19.8	29.0	13.6	43.0	12.7
46.0	16.0	51.5	18.0	30.5	12.7	44.0	12.3
49.0	13.6	54.0	15.9	34.5	10.7	47.0	9.0
51.0	9.0	56.0	12.7	36.5	9.6	51.0	7.6
54.0	6.8	58.0	9.0	42.0	8.3	57.0	4.8
58.0	4.8	60.5	5.9	47.0	6.8	63.5	4.3
60.5	3.4	64.0	3.4	55.5	4.8		

HW = 70.0 ft, G_o = 24.75 ft		HW = 70.0 ft, G_o = 28.83 ft		HW = 70.0 ft, G_o = 36.19 ft		HW = 70.0 ft, G_o = 43.0 ft	
Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps	Tailwater El	Velocity Downstream fps
14.0	33.5	16.5	33.3	20.5	36.8	51.0	22.6
38.5	20.9	41.0	22.5	46.5	20.9	54.0	20.4
40.5	18.0	44.0	21.5	51.5	19.2	59.5	18.6
44.5	15.2	48.5	17.3	54.5	17.3	62.5	13.6
46.5	14.4	52.0	10.0	56.5	14.4	64.0	12.3
50.0	9.6	55.0	6.9	59.0	10.7	66.0	6.8
52.0	5.9	58.5	4.8	61.0	5.9	69.0	4.8
58.0	4.8	63.0	3.4	63.5	3.7		
64.0	3.4	67.5	2.8	69.0	2.8		

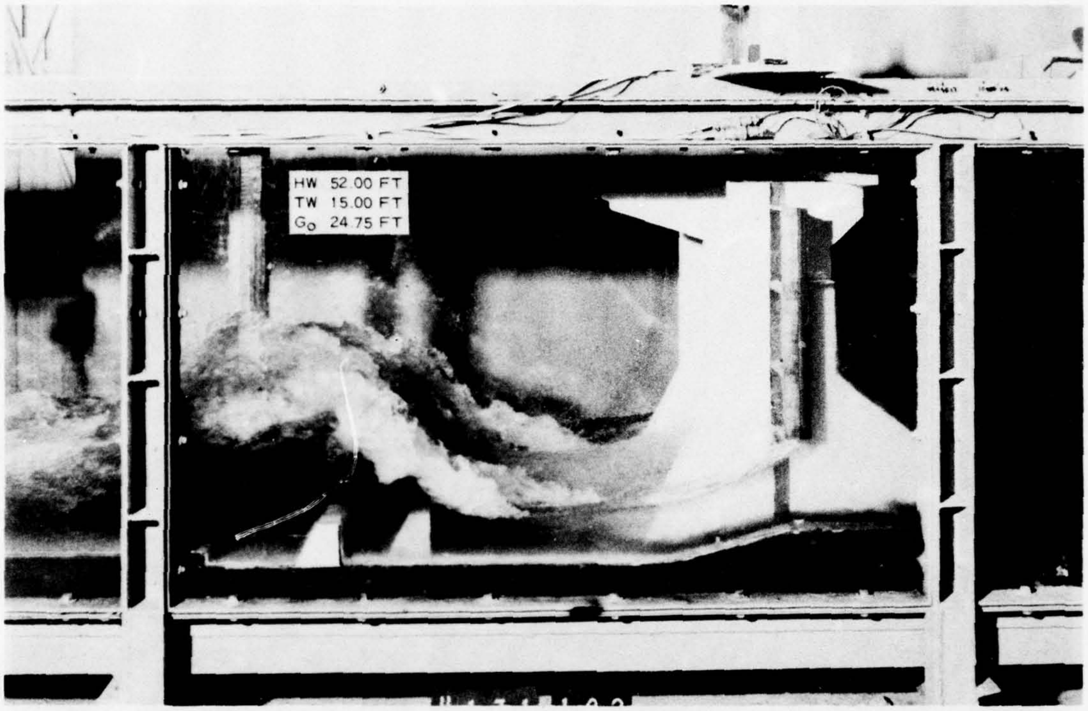


Photo 1. Supercritical spray, low gate bays, *controlled (orifice)* flow

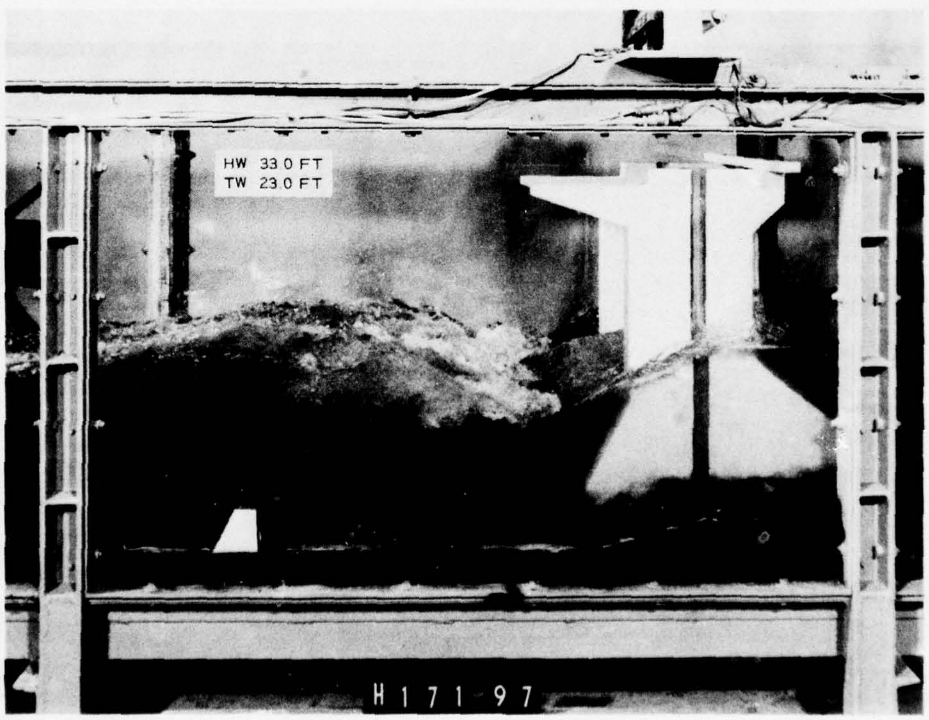
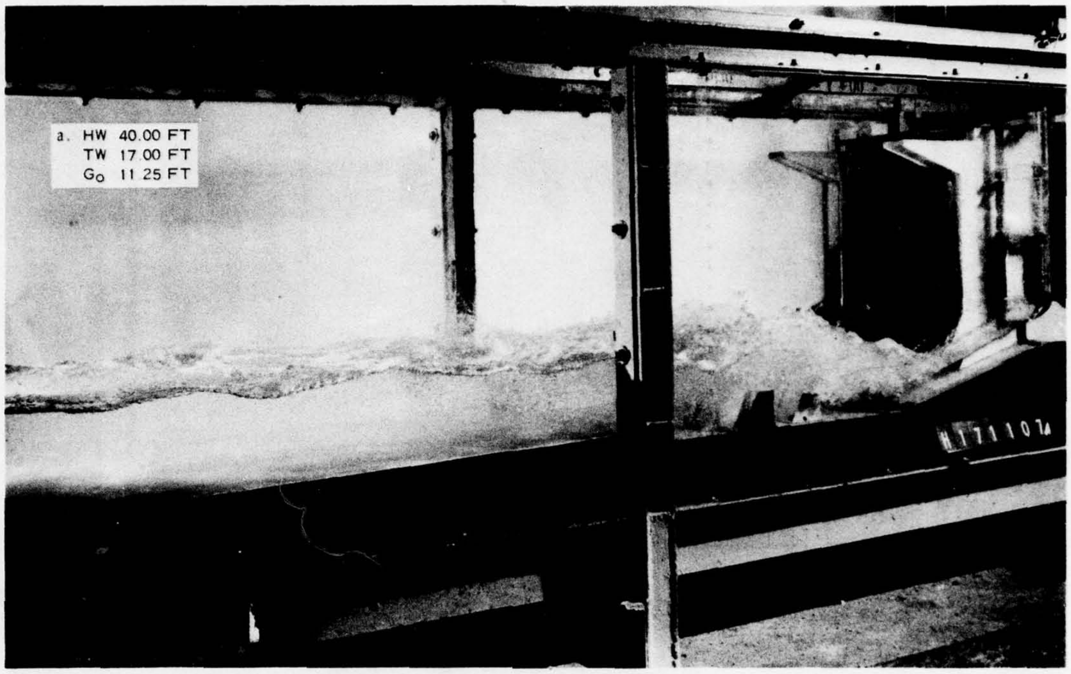


Photo 2. Forced jump with supercritical flow in exit channel, low gate bays, uncontrolled flow



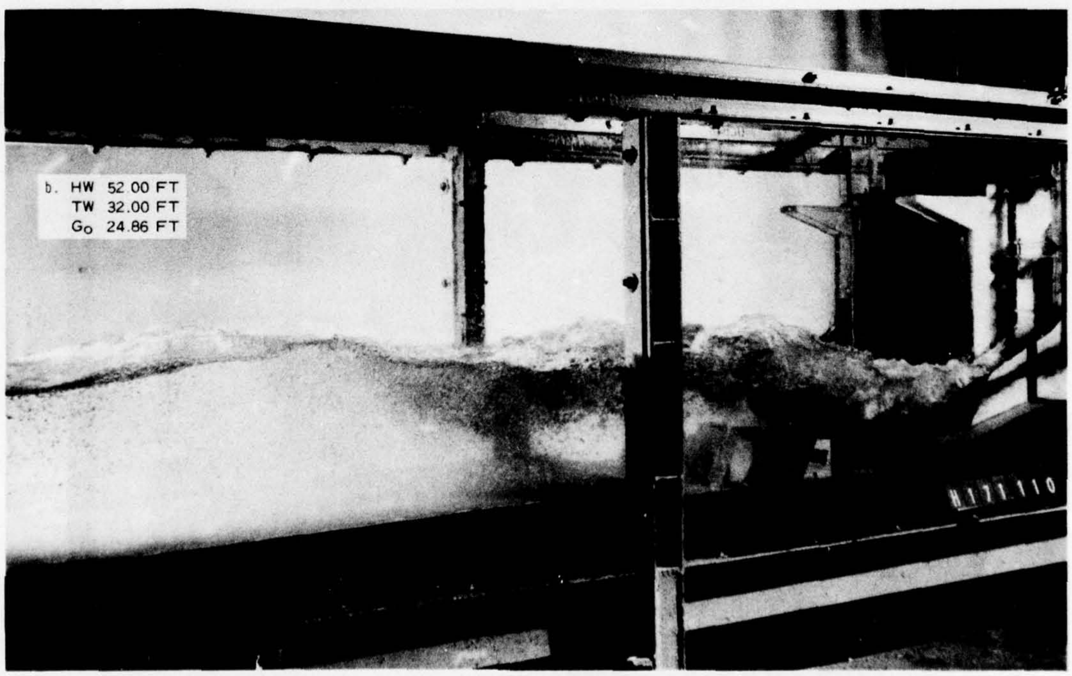
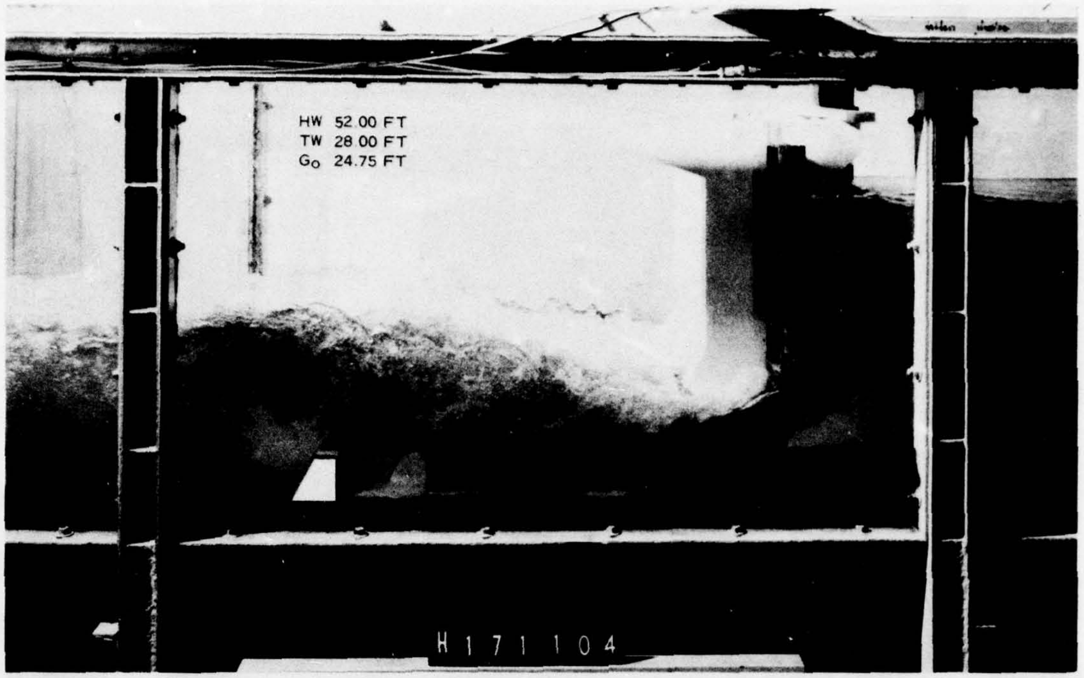
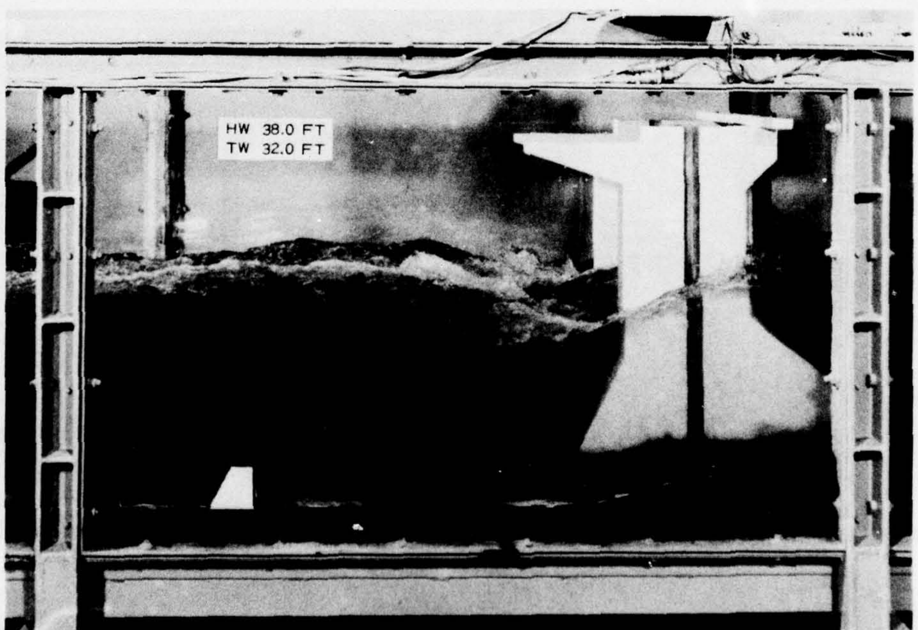


Photo 3. Hydraulic jump with standing waves in exit channel, high gate bays

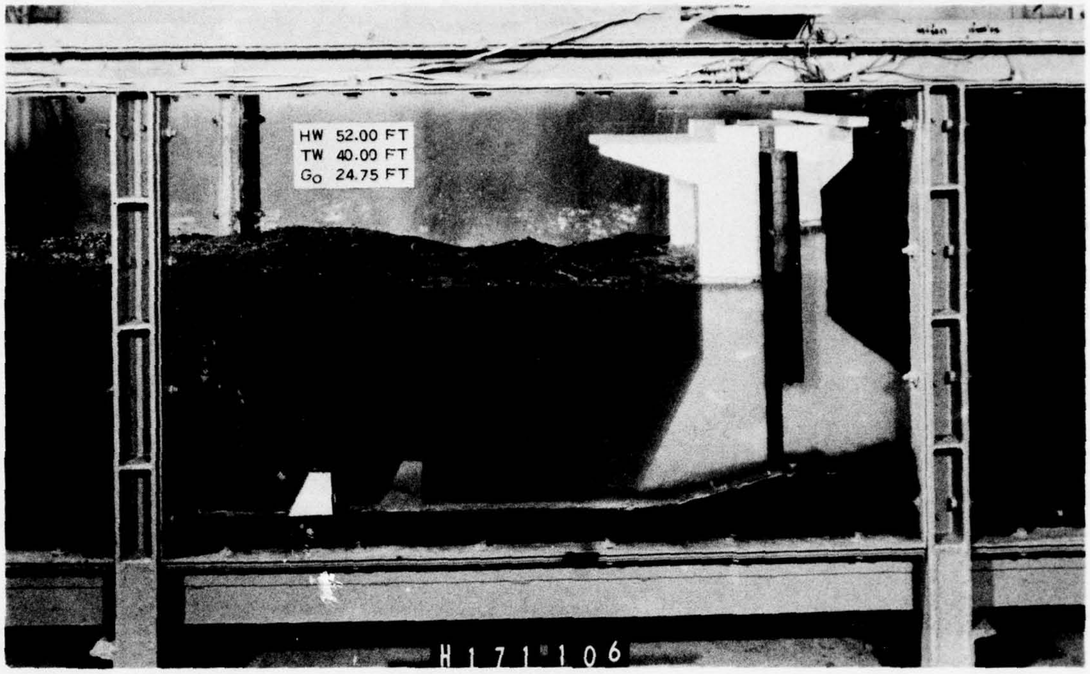


a. Controlled (orifice) flow

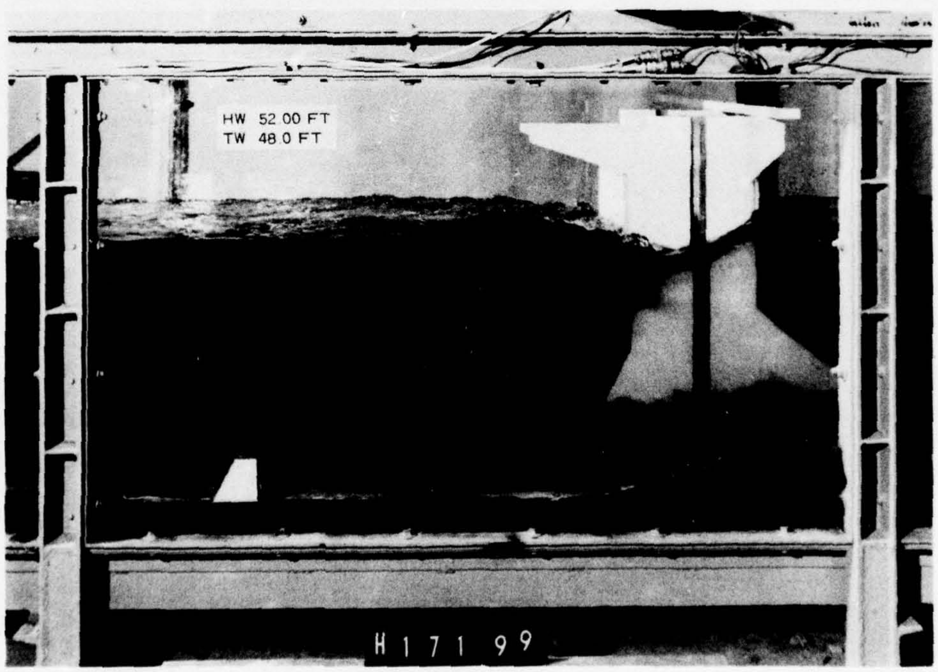


b. Uncontrolled flow

Photo 4. Hydraulic jump action, low gate bays

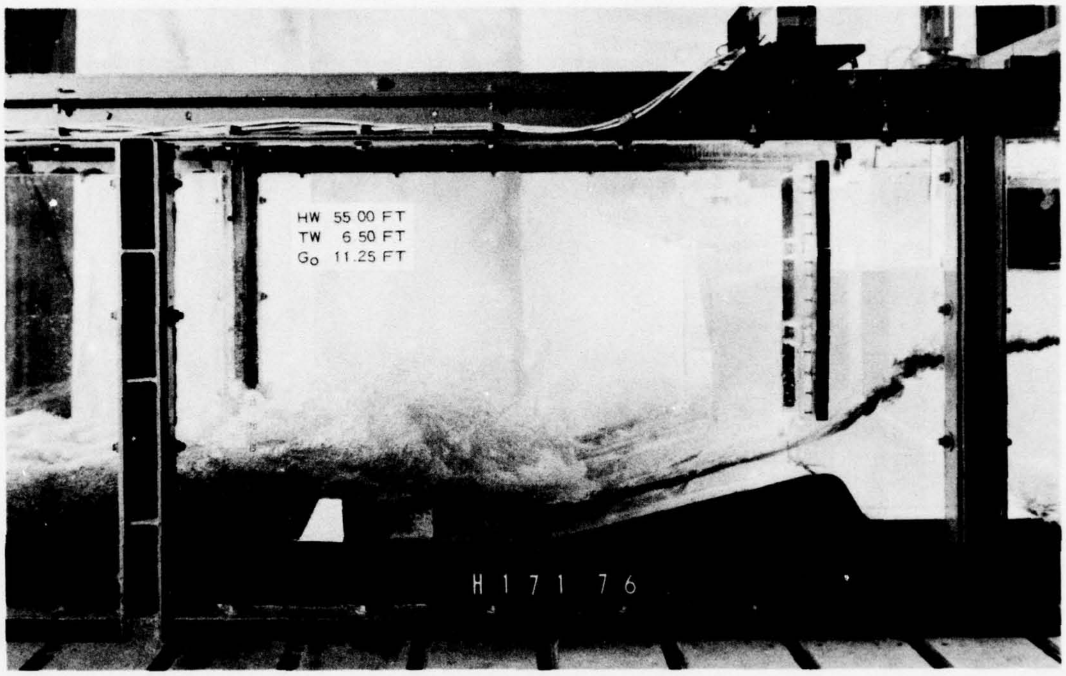


a. Controlled (orifice) flow

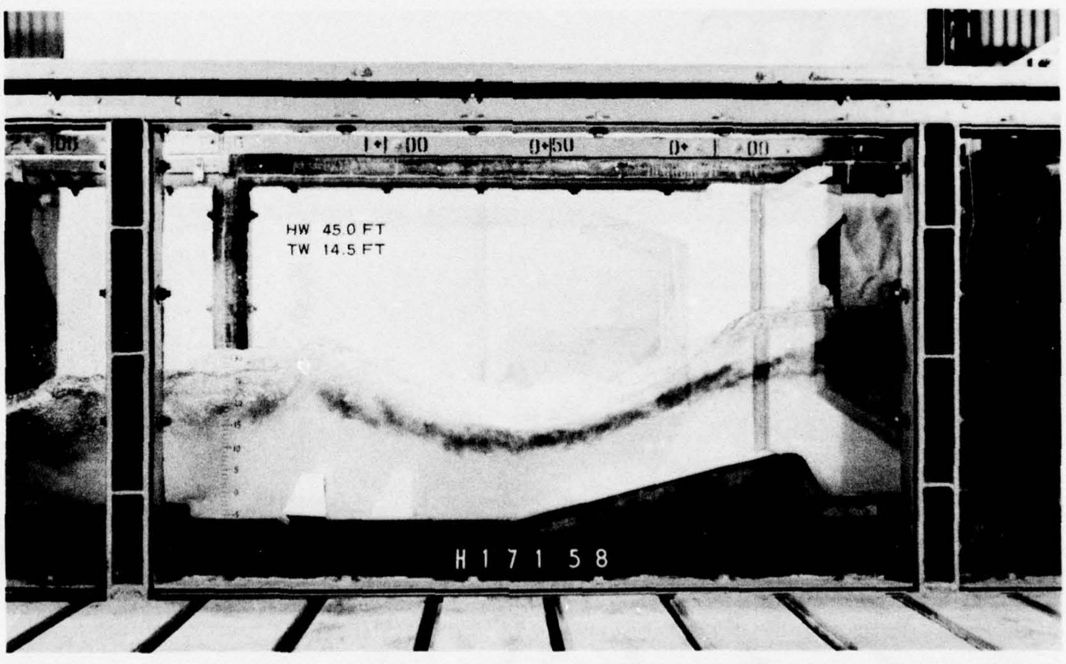


b. Uncontrolled flow

Photo 5. Submerged jump, low gate bays

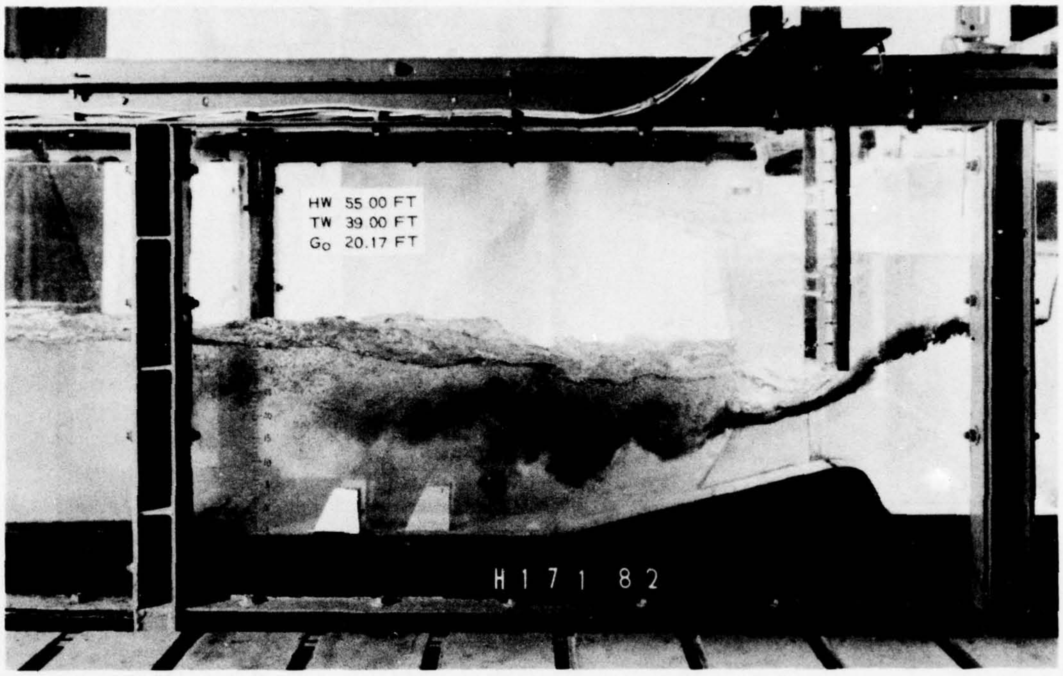


a. Controlled flow

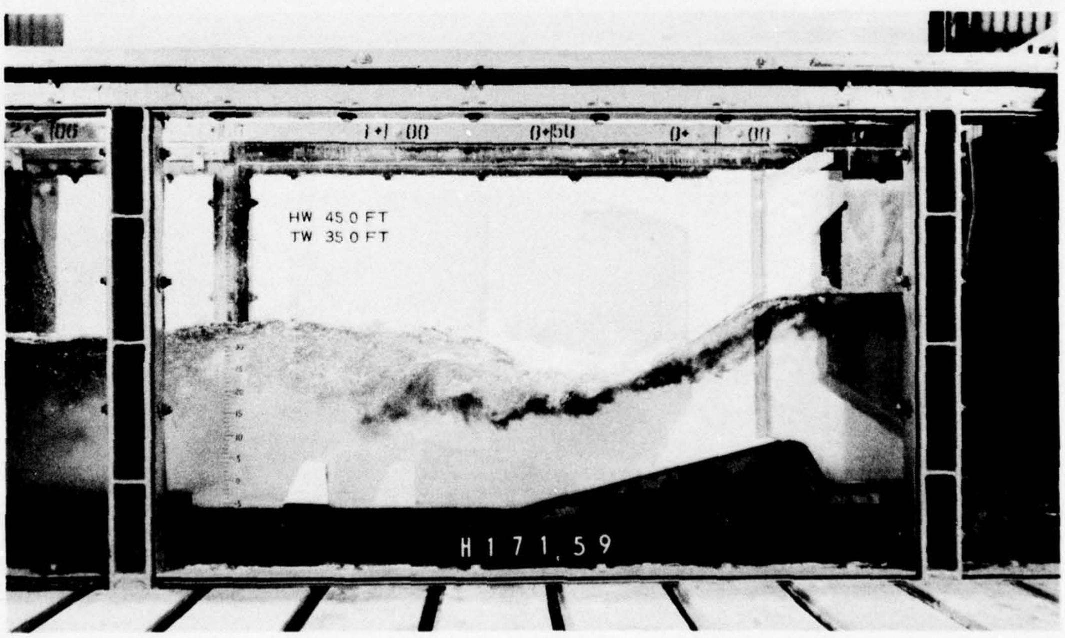


b. Uncontrolled flow

Photo 6. Forced jump with supercritical flow in exit channel, high gate bays

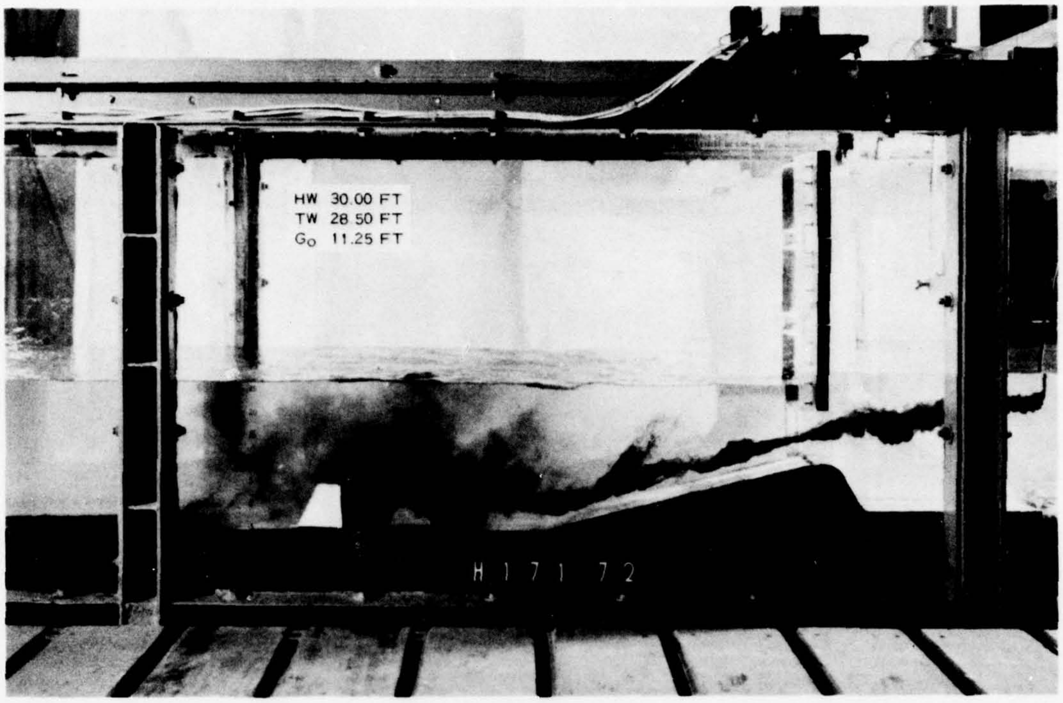


a. Controlled flow

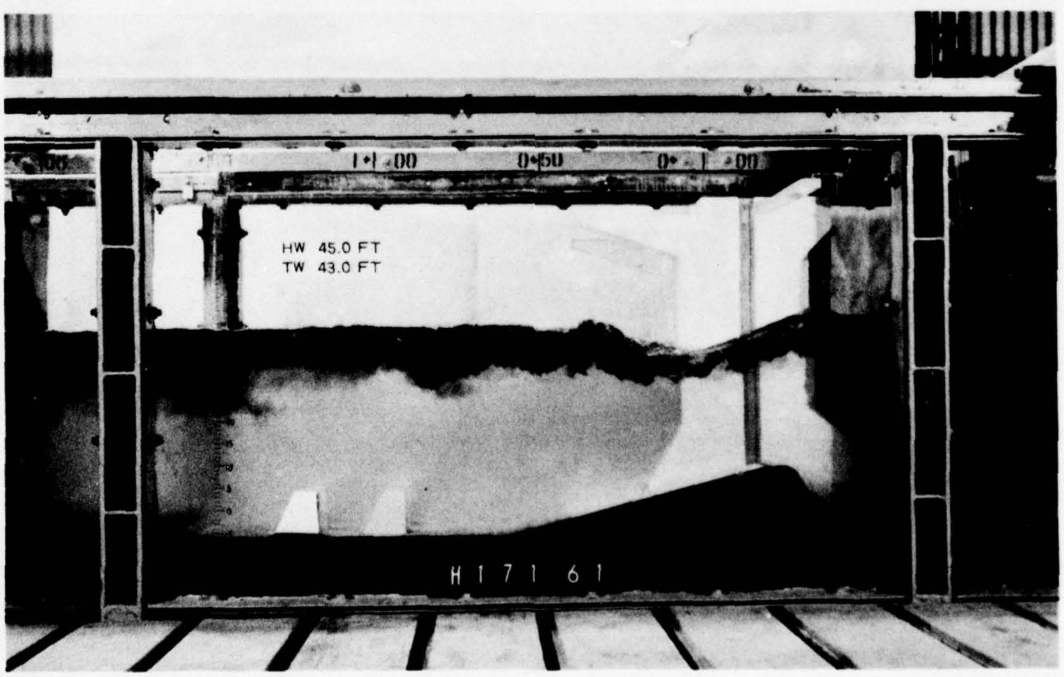


b. Uncontrolled flow

Photo 7. Hydraulic jump, high gate bays

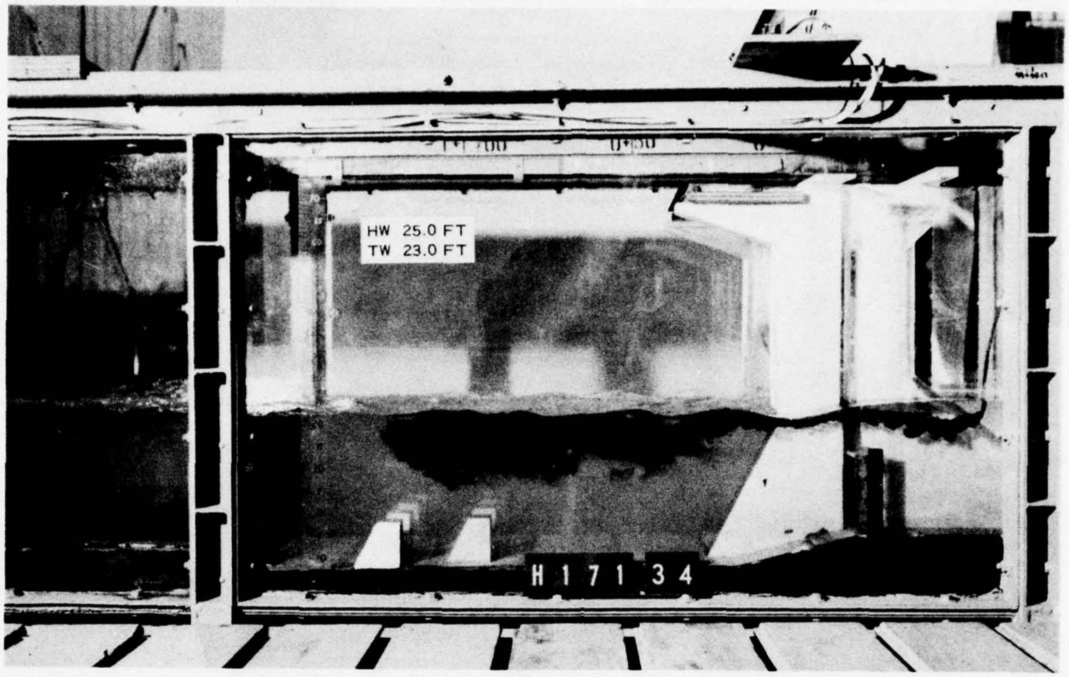


a. Controlled (orifice) flow

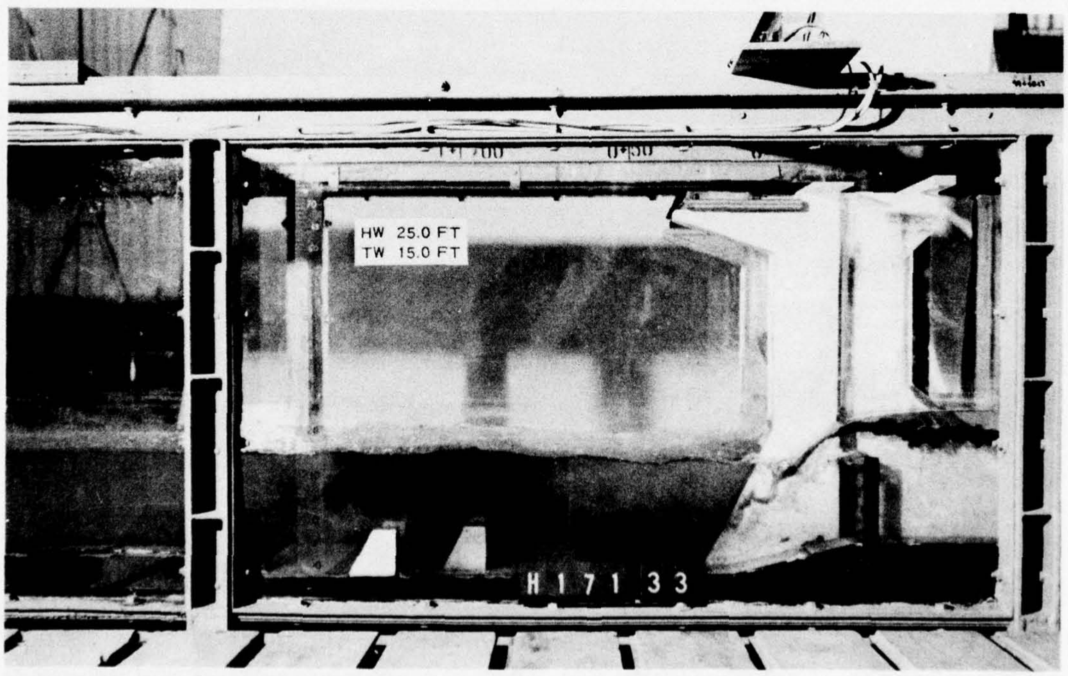


b. Uncontrolled flow

Photo 8. Submerged jump, high gate bays

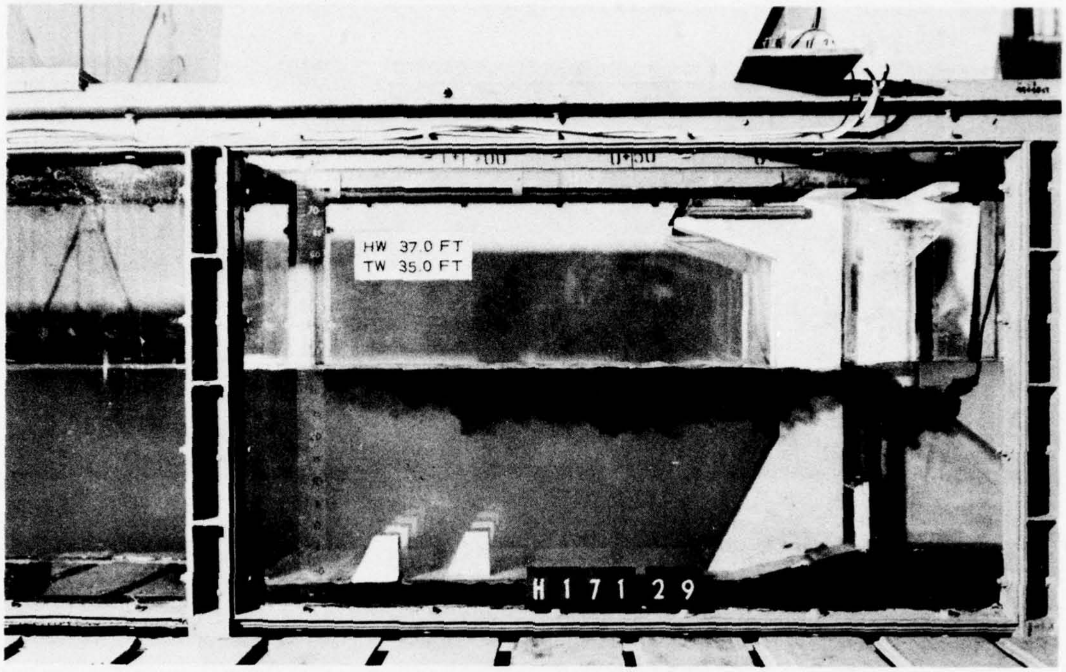


a. Riding nappe, surface jet

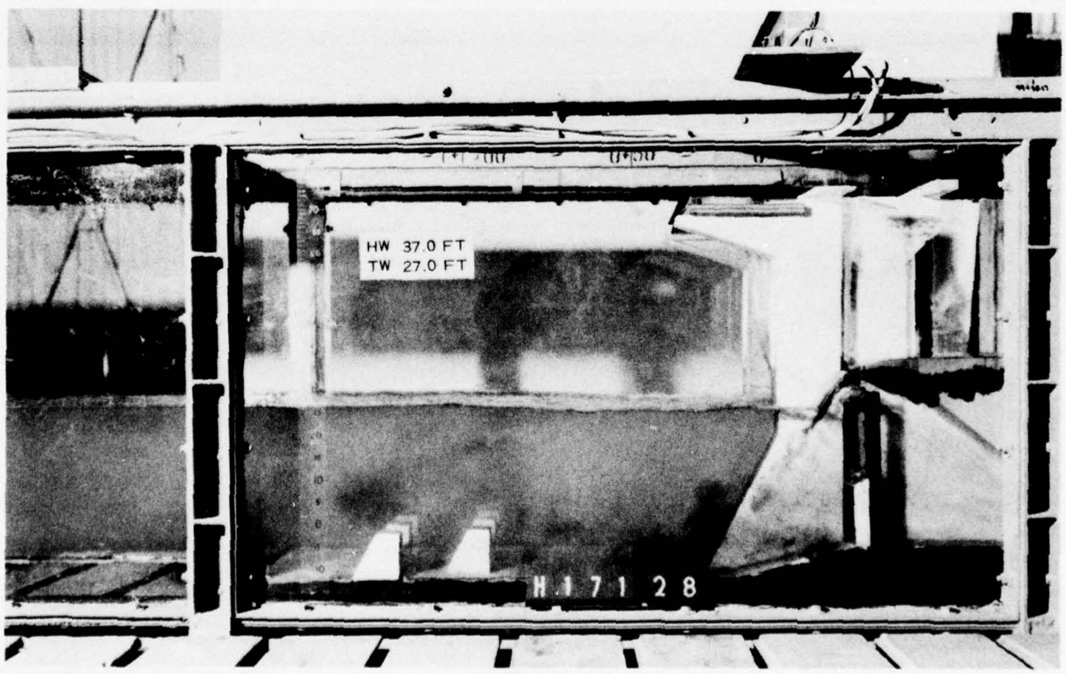


b. Plunging nappe, hydraulic jump

Photo 9. Stilling basin performance with gate leaf 4L in low gate bays, weir el 10.0

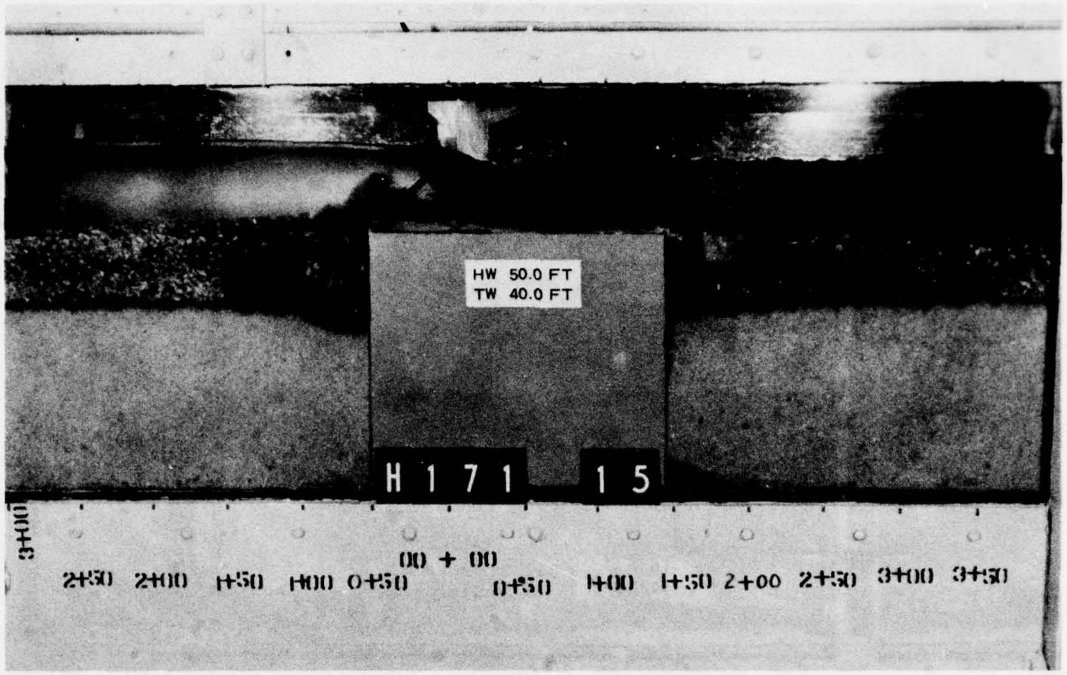


a. Riding nappe, surface jet

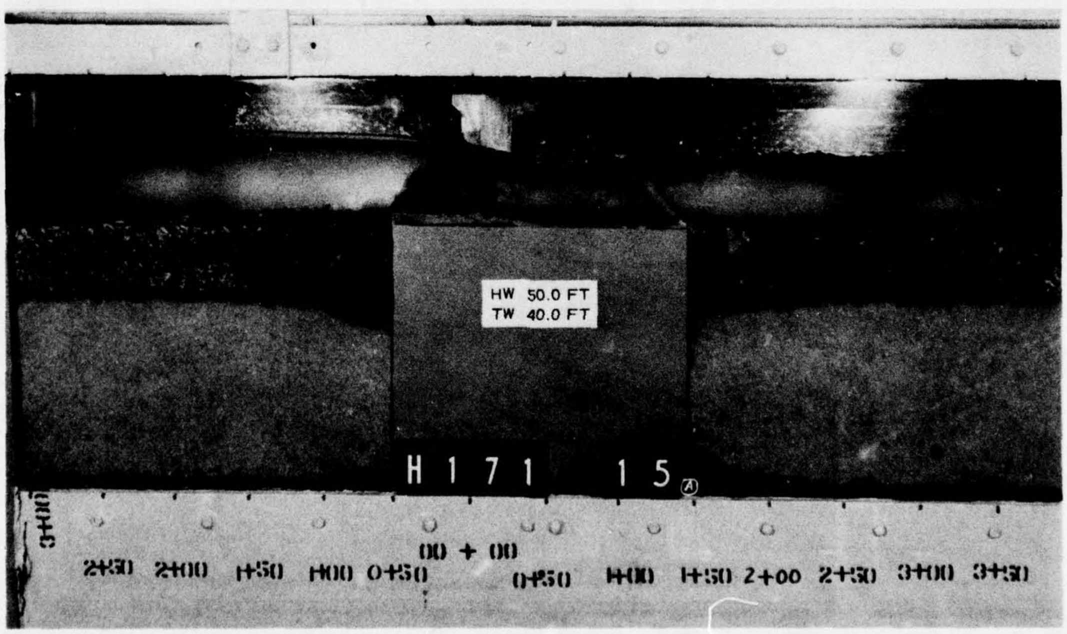


b. Plunging nappe, submerged jump

Photo 10. Stilling basin performance with gate leaves 4L and 3L in gate bays, weir el 29.0



a. Maximum degree of turbulence in approach with gate 6 closed, gates 5 and 7 open



b. Minimum degree of turbulence in approach with gate 6 closed, gates 5 and 7 open

Photo 11. Approach turbulence with one gate fully open, low gate bays

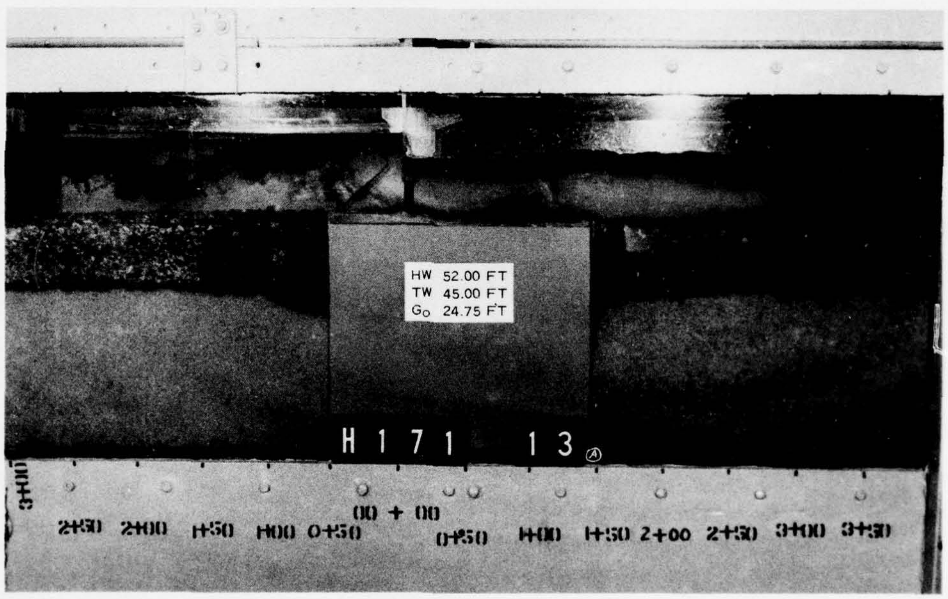
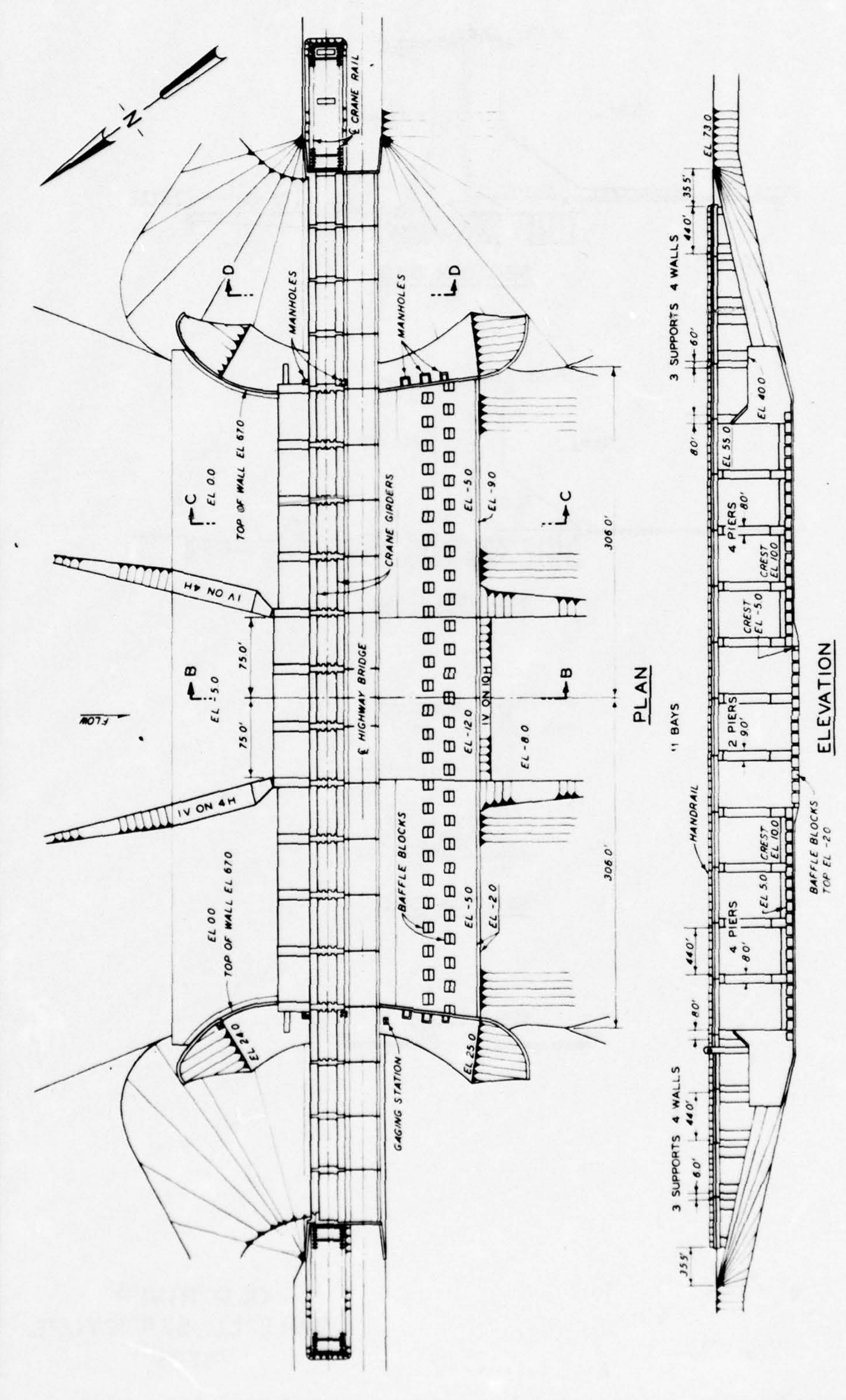
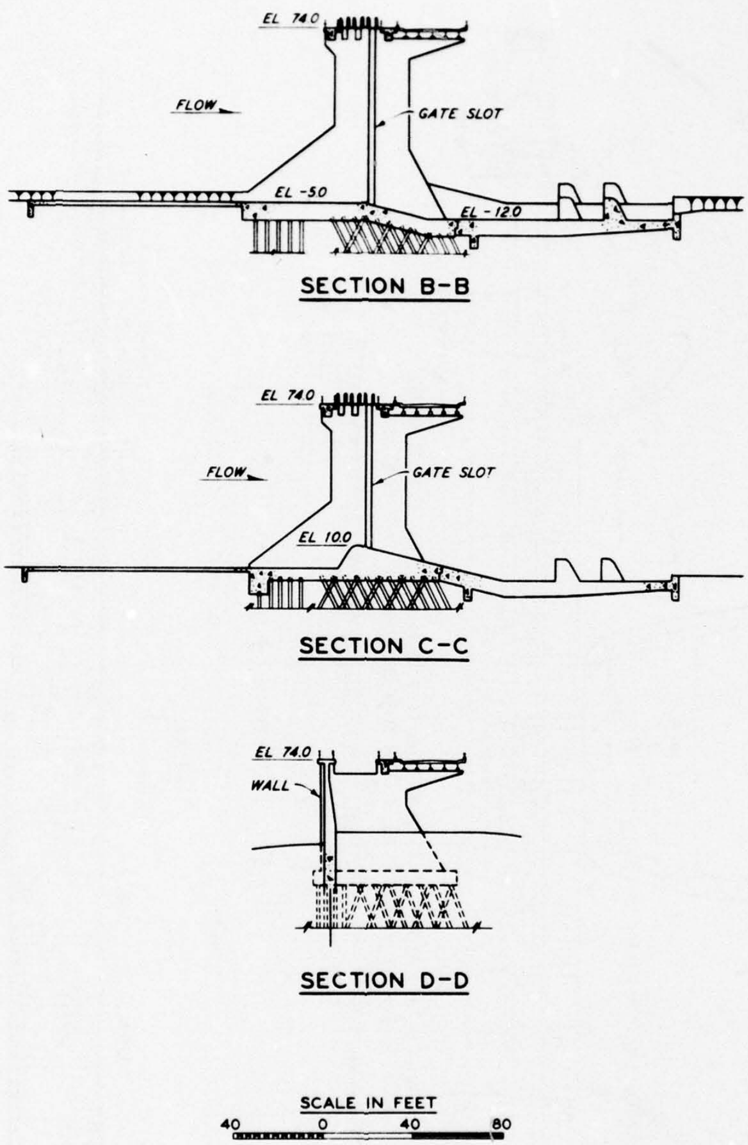


Photo 12. Approach flow conditions with orifice or controlled flow conditions, low gate bays

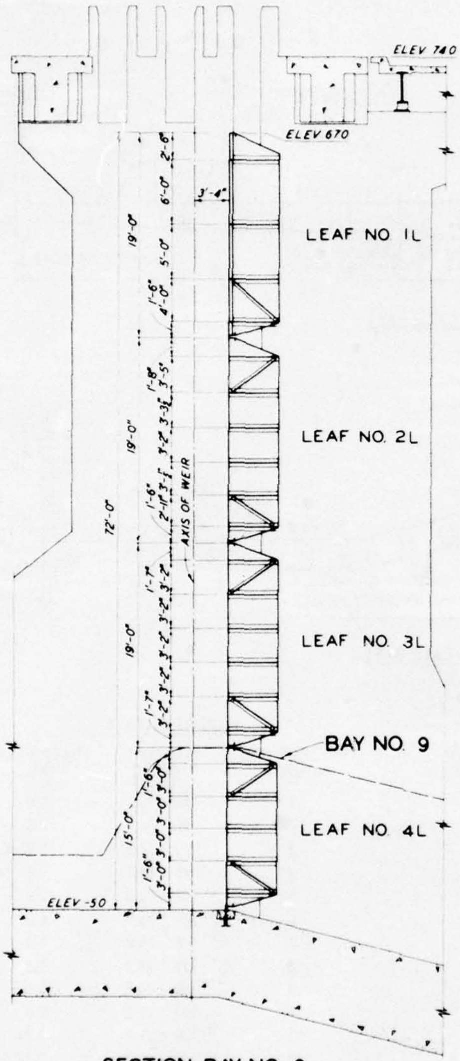


OLD RIVER LOW-SILL STRUCTURE
PLAN AND ELEVATION



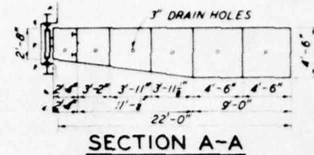
OLD RIVER
LOW-SILL STRUCTURE
PIERS

PLATE 2

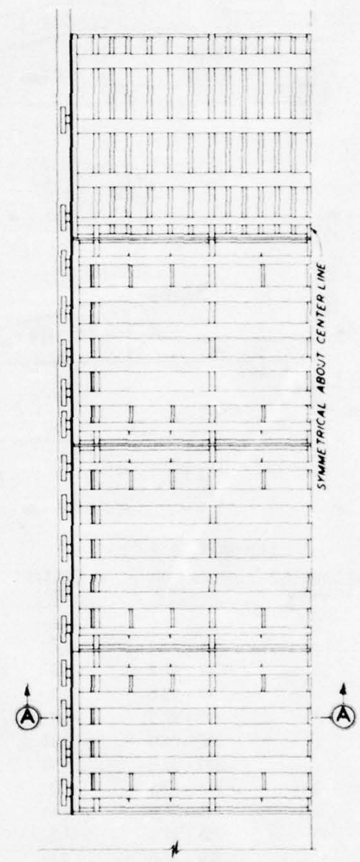


SECTION BAY NO. 6

SCALE IN FEET



SECTION A–A



ELEVATION

NOTE: SECTION A-A TYPICAL FOR GATE LEAVES NO. 3L AND 4L.

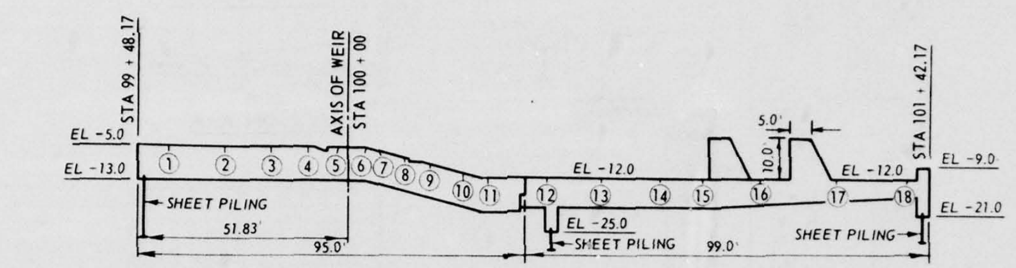
	WEIR BAYS				LOW FLOW BAYS			WEIR BAYS			
LEAF NO.	1W	1W	1W	1W	1L	1L	1L	1W	1W	1W	1W
LEAF NO.	2W	2W	2W	2W	2L	2L	2L	2W	2W	2W	2W
LEAF NO.	3W	3W	3W	3W	3L	3L	3L	3W	3W	3W	3W
LEAF NO.					4L	4L	4L				

GATE LEAF ARRANGEMENT

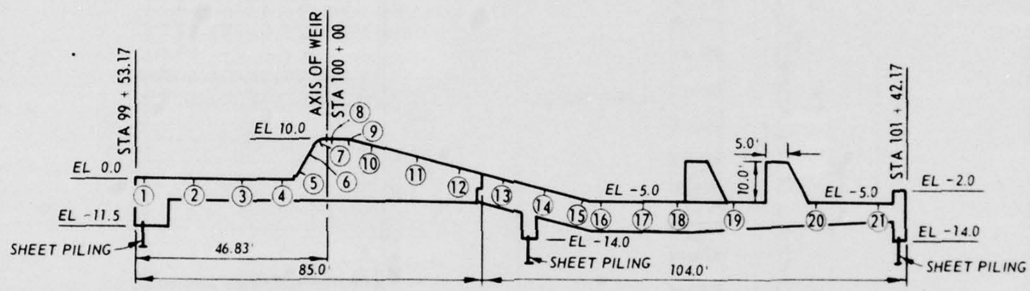
NOT TO SCALE

STRUCTURAL DETAILS OF GATE LEAVES

PLATE 3



LOW GATE BAYS



HIGH GATE BAYS

LOW GATE BAYS

PIEZOMETER NUMBER	*STATION NUMBER	ELEVATION FT
1	99 + 57.0	-5.0
2	99 + 72.0	-5.0
3	99 + 86.2	-5.0
4	99 + 90.0	-5.0
5	99 + 97.5	-5.0
6	100 + 04.0	-5.75
7	100 + 06.0	-5.47
8	100 + 12.5	-7.02
9	100 + 20.0	-8.81
10	100 + 30.0	-11.2
11	100 + 38.0	-12.0
12	100 + 53.0	-12.0
13	100 + 63.0	-12.0
14	100 + 73.0	-12.0
15	100 + 87.0	-12.0
16	100 + 99.0	-12.0
17	101 + 19.0	-12.0
18	101 + 36.0	-12.0

* REFERRED TO AXIS OF WEIR STATION 100 + 00

NOTE: PIEZOMETERS ARE LOCATED AT CENTER LINE AND ALONG THE INSIDE LEFT PIER OF GATE BAY 6, LOOKING DOWNSTREAM OF THE STRUCTURE.

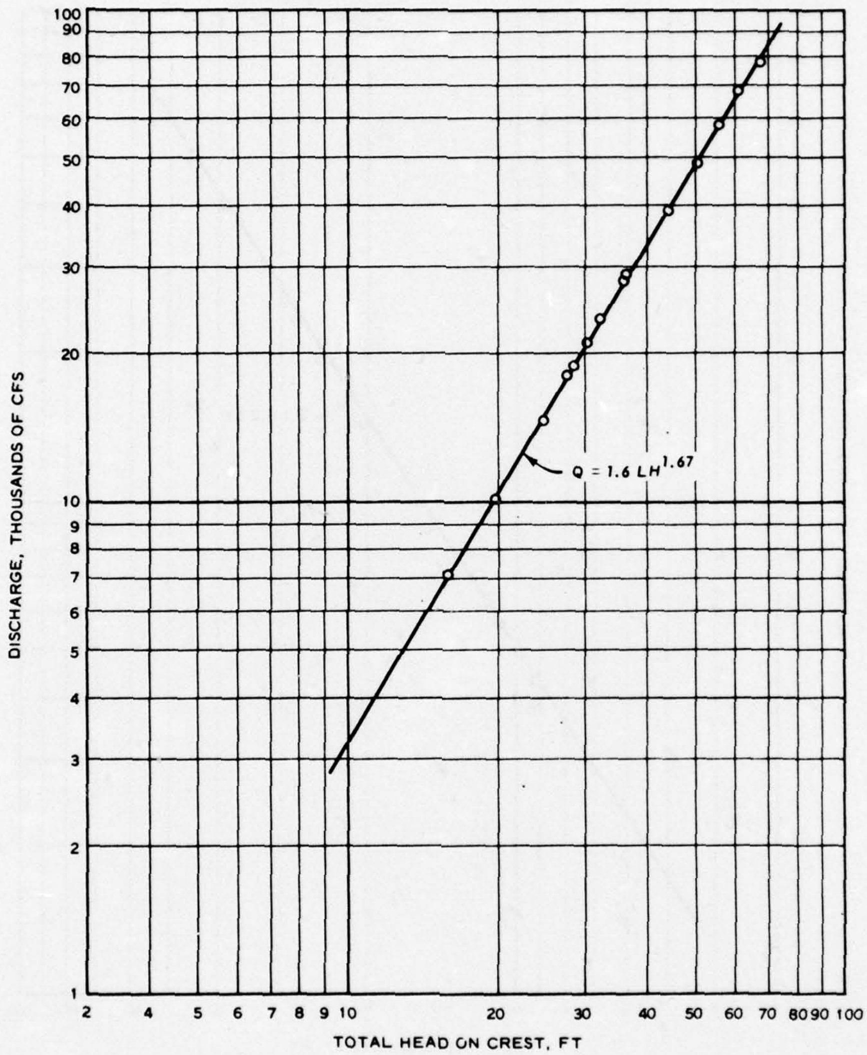
HIGH GATE BAYS

PIEZOMETER NUMBER	*STATION NUMBER	ELEVATION FT
1	99 + 55.0	0.0
2	99 + 66.0	0.0
3	99 + 77.0	0.0
4	99 + 88.7	0.0
5	99 + 94.0	2.0
6	99 + 96.0	6.0
7	99 + 98.0	9.0
8	100 + 02.0	10.0
9	100 + 04.7	10.0
10	100 + 10.2	8.6
11	100 + 21.7	5.74
12	100 + 29.8	3.72
13	100 + 47.7	-0.75
14	100 + 52.7	-2.0
15	100 + 60.7	-4.0
16	100 + 70.7	-5.0
17	100 + 80.7	-5.0
18	100 + 85.7	-5.0
19	101 + 02.7	-5.0
20	101 + 20.7	-5.0
21	101 + 34.7	-5.0

* REFERRED TO AXIS OF WEIR STATION 100 + 00

NOTE: PIEZOMETERS ARE LOCATED AT THE CENTER LINE AND ALONG THE INSIDE LEFT PIER, LOOKING DOWNSTREAM OF THE STRUCTURE.

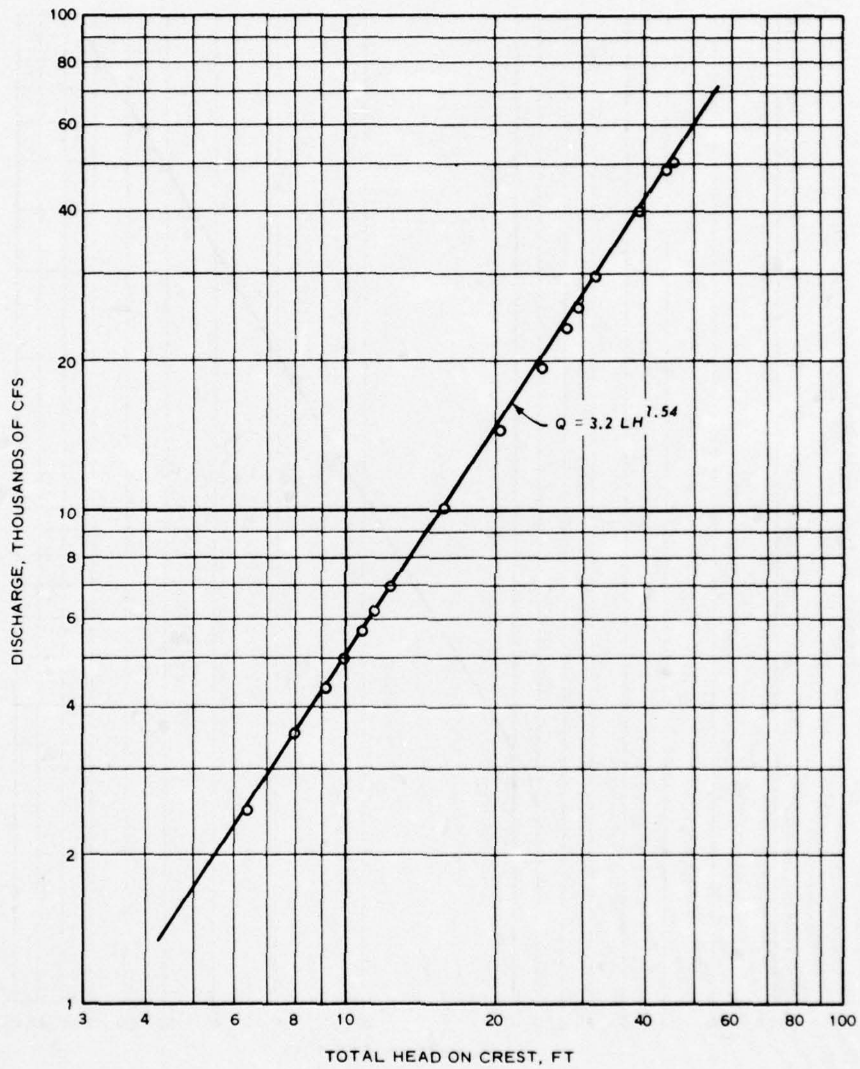
PIEZOMETER LOCATIONS



NOTE: FLOW THROUGH ONE BAY

HEAD-DISCHARGE RELATIONSHIP
FOR FREE UNCONTROLLED FLOW
LOW GATE BAYS

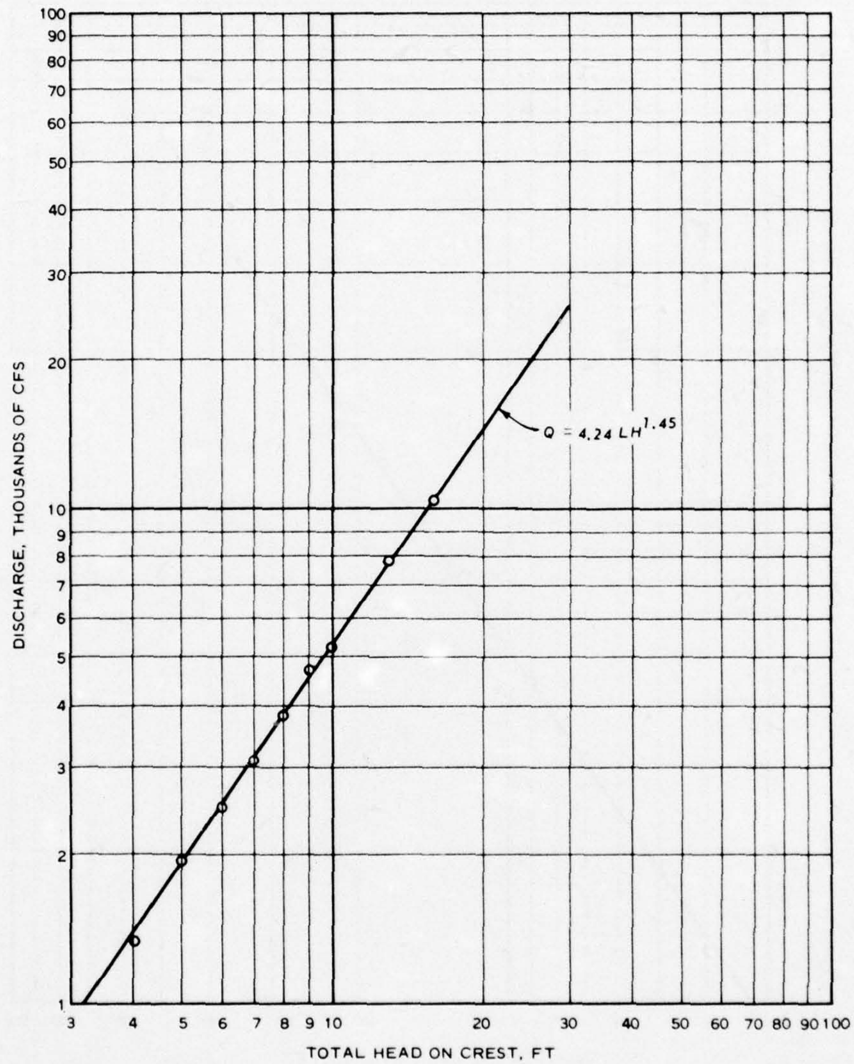
CREST ELEVATION -5.0 FT



NOTE: FLOW THROUGH ONE BAY

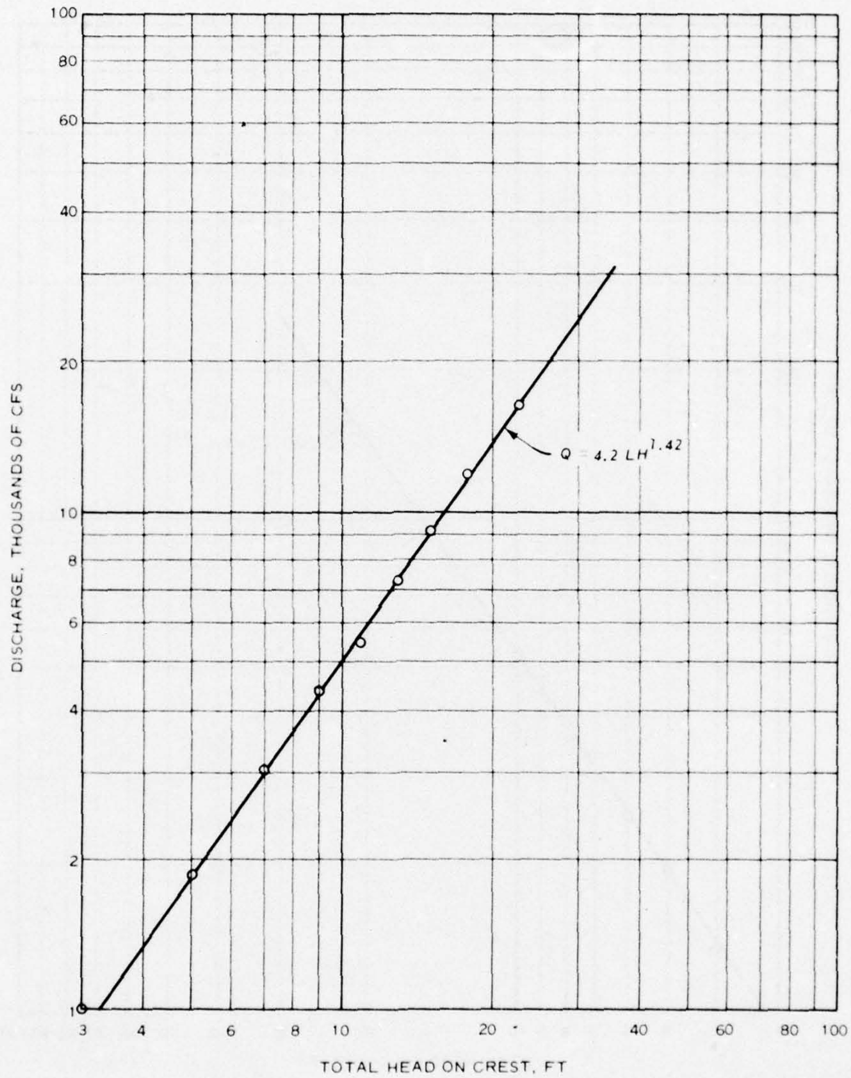
HEAD-DISCHARGE RELATIONSHIP FOR FREE UNCONTROLLED FLOW HIGH GATE BAYS

CREST ELEVATION 10.0 FT

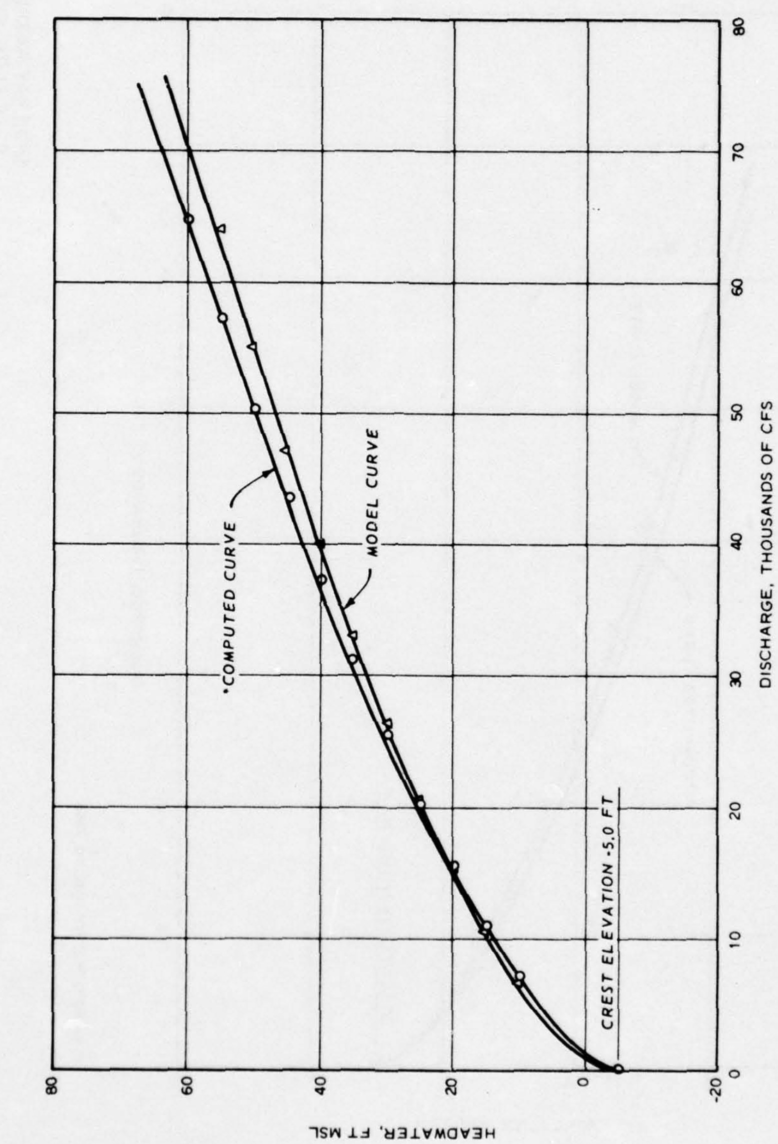


HEAD-DISCHARGE RELATIONSHIP FOR FREE WEIR FLOW GATE LEAF 4L IN LOW GATE BAYS

WEIR ELEVATION 10.0 FT

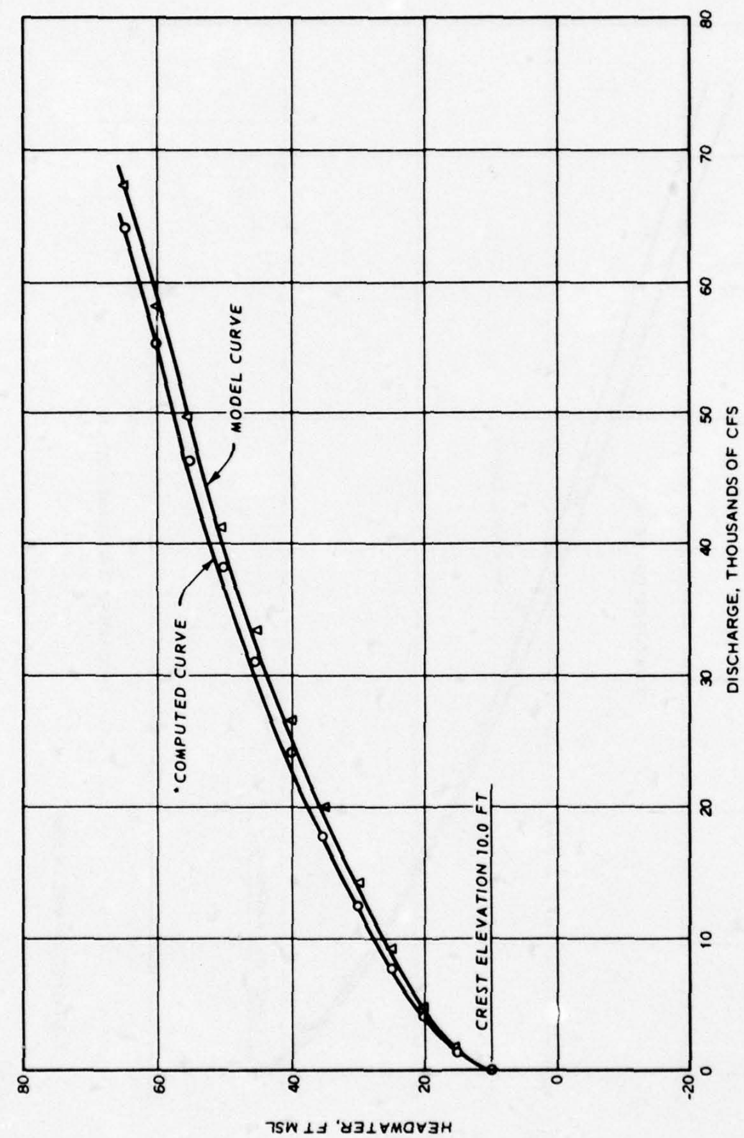


HEAD-DISCHARGE RELATIONSHIP
FOR FREE WEIR FLOW
LEAVES 4L & 3L IN LOW GATE BAYS
WEIR ELEVATION 29.0 FT



* COMPUTED BY MRC IN 1966

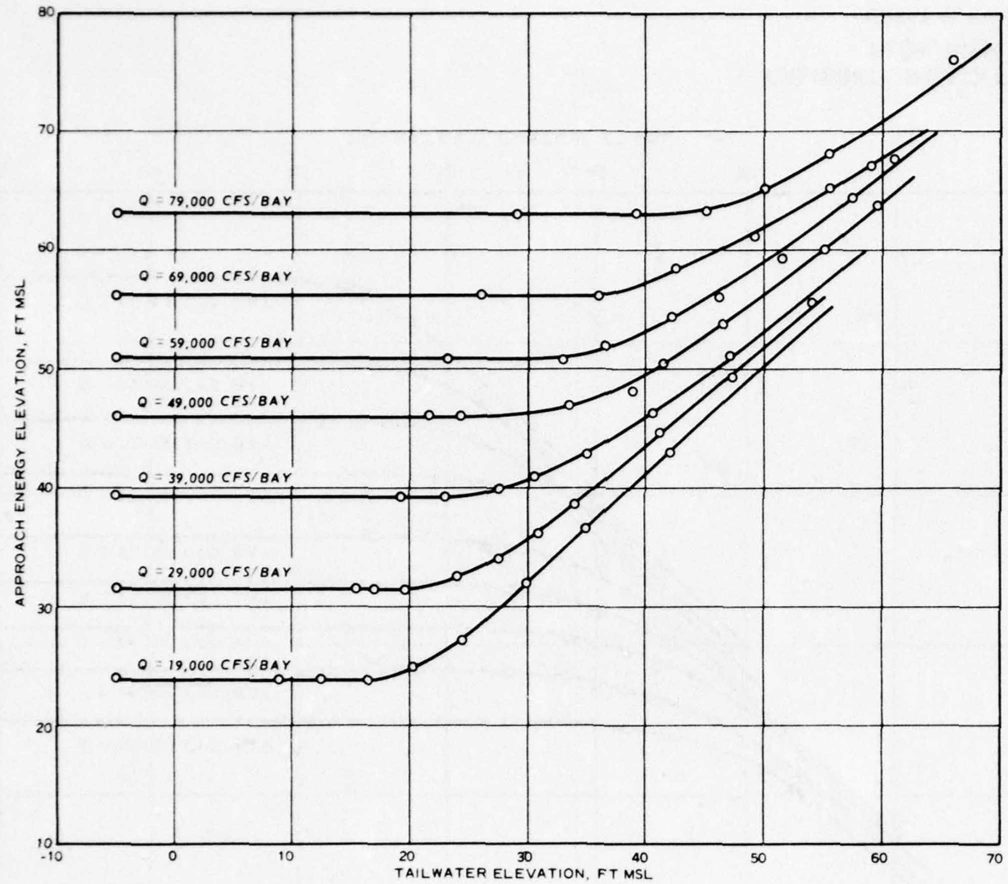
SPILLWAY RATING CURVES FOR
FREE FLOW, LOW GATE BAYS
CREST ELEVATION -5.0 FT



* COMPUTED BY MRC IN 1966

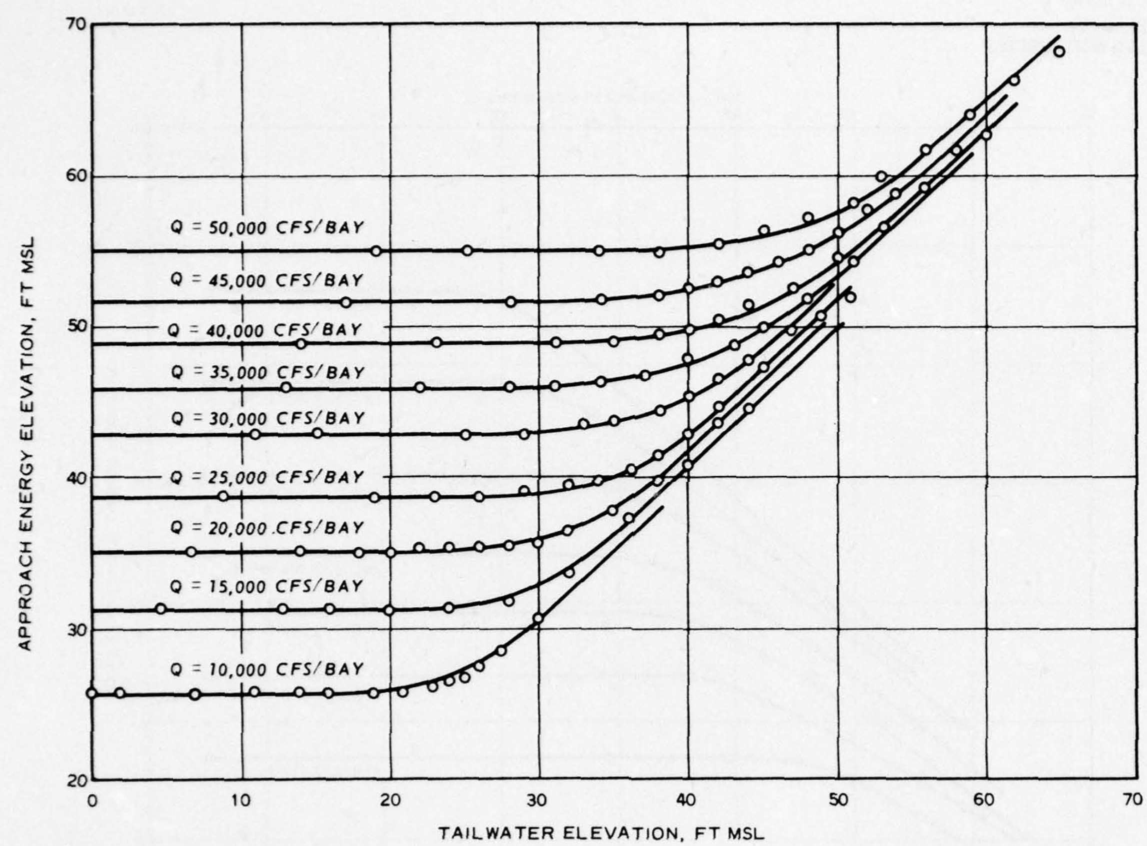
SPILLWAY RATING CURVES FOR FREE FLOW, HIGH GATE BAYS

CREST ELEVATION 10.0 FT



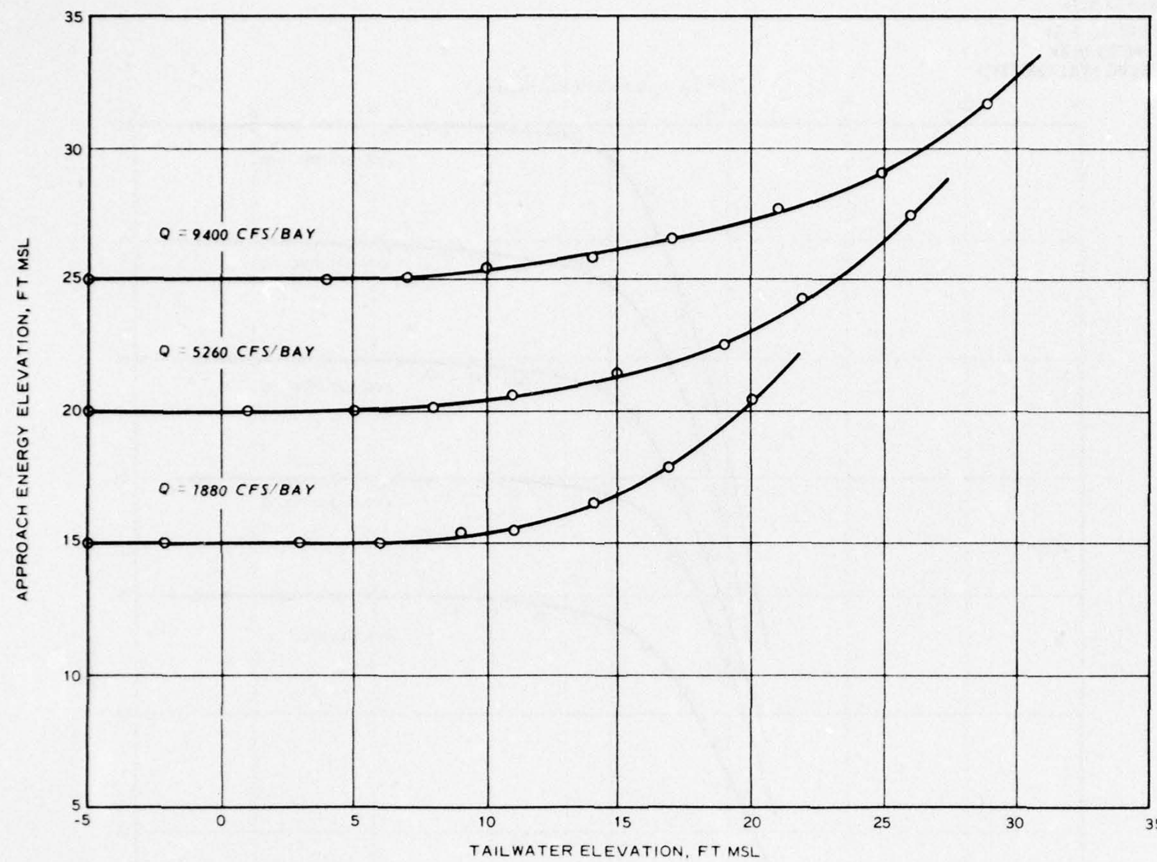
CALIBRATION DATA FOR UNCONTROLLED FLOW, LOW GATE BAYS

CREST ELEVATION -5.0 FT



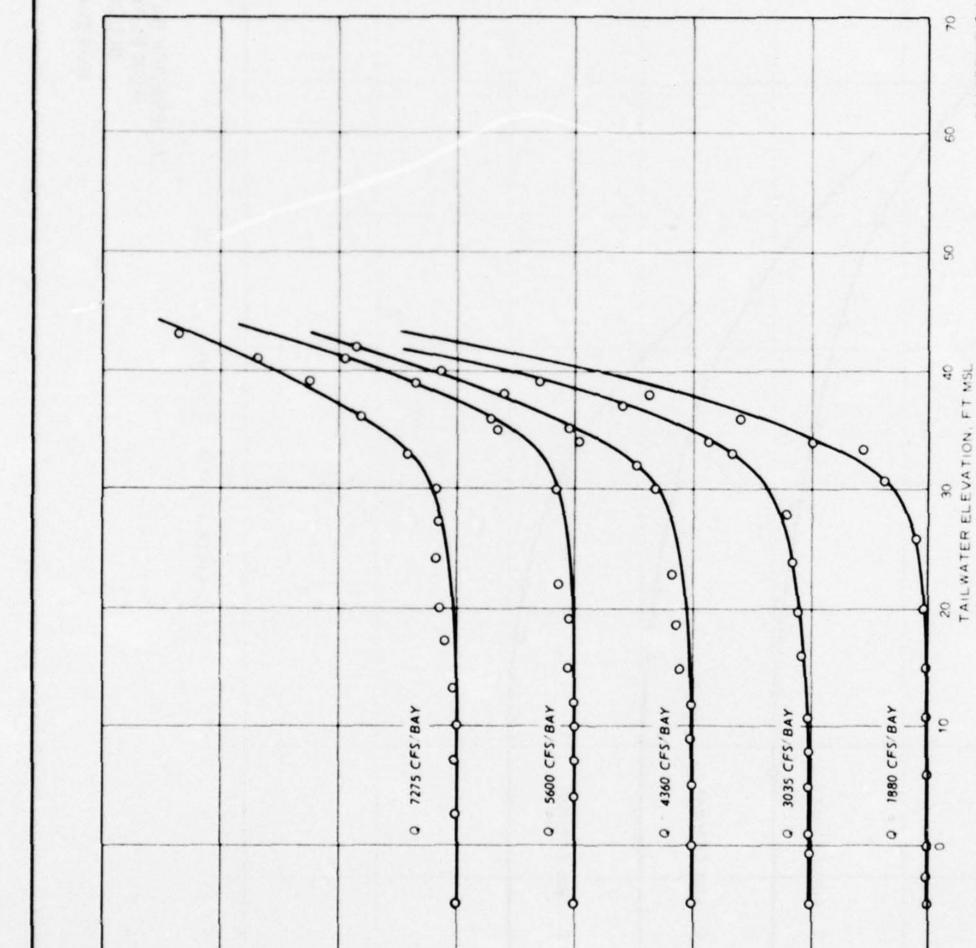
CALIBRATION DATA FOR UNCONTROLLED FLOW, HIGH GATE BAYS

CREST ELEVATION 10.0 FT



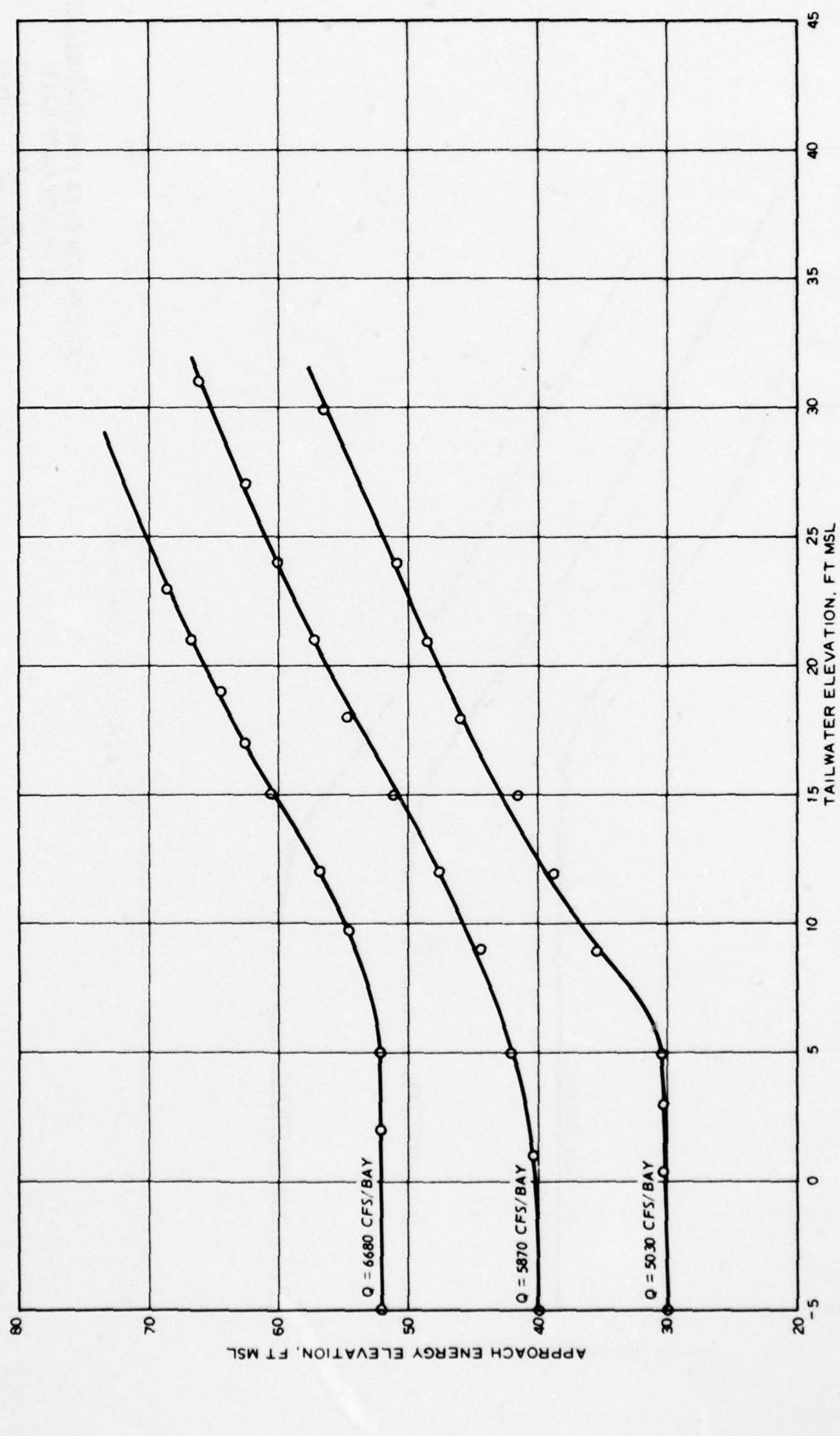
CALIBRATION DATA FOR UNCONTROLLED
WEIR FLOW, GATE LEAF 4L
IN LOW GATE BAYS

WEIR ELEVATION 10.0 FT



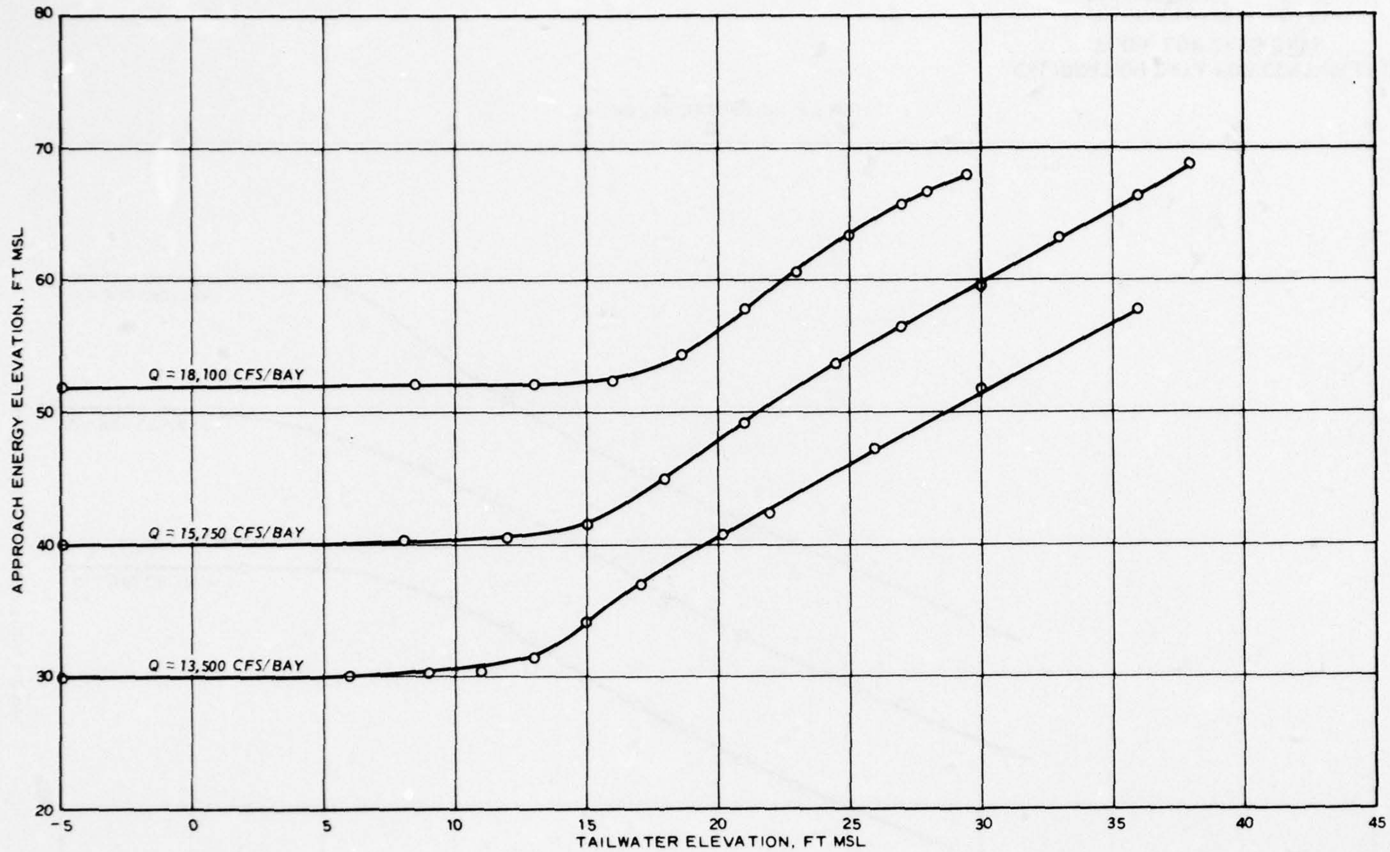
CALIBRATION DATA FOR UNCONTROLLED
WEIR FLOW, GATE LEAVES
4L & 3L IN LOW GATE BAYS
WEIR ELEVATION 29.0 FT

PLATE 14



CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAYS

CREST ELEVATION -5.0 FT
GATE OPENING 4.0 FT

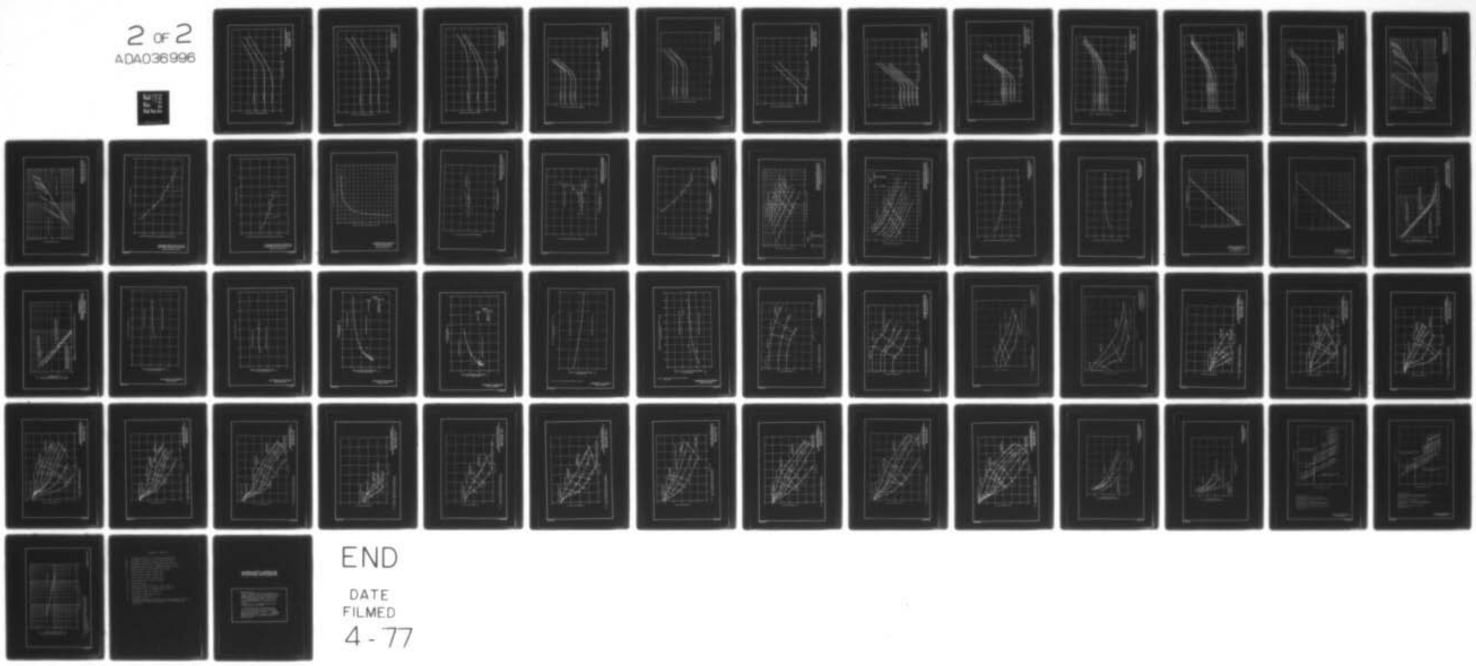


CALIBRATION DATA FOR CONTROLLED
FLOW, LOW GATE BAYS

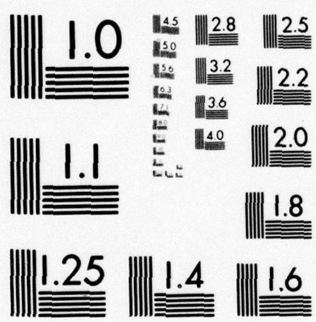
CREST ELEVATION -5.0 FT
GATE OPENING 11.25 FT

AD-A036 996 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/2
OLD RIVER EXISTING LOW-SILL CONTROL STRUCTURE, LOUISIANA; HYDRA--ETC(U)
FEB 77 E D ROTHWELL, J L GRACE
UNCLASSIFIED WES-TR-H-77-2 NL

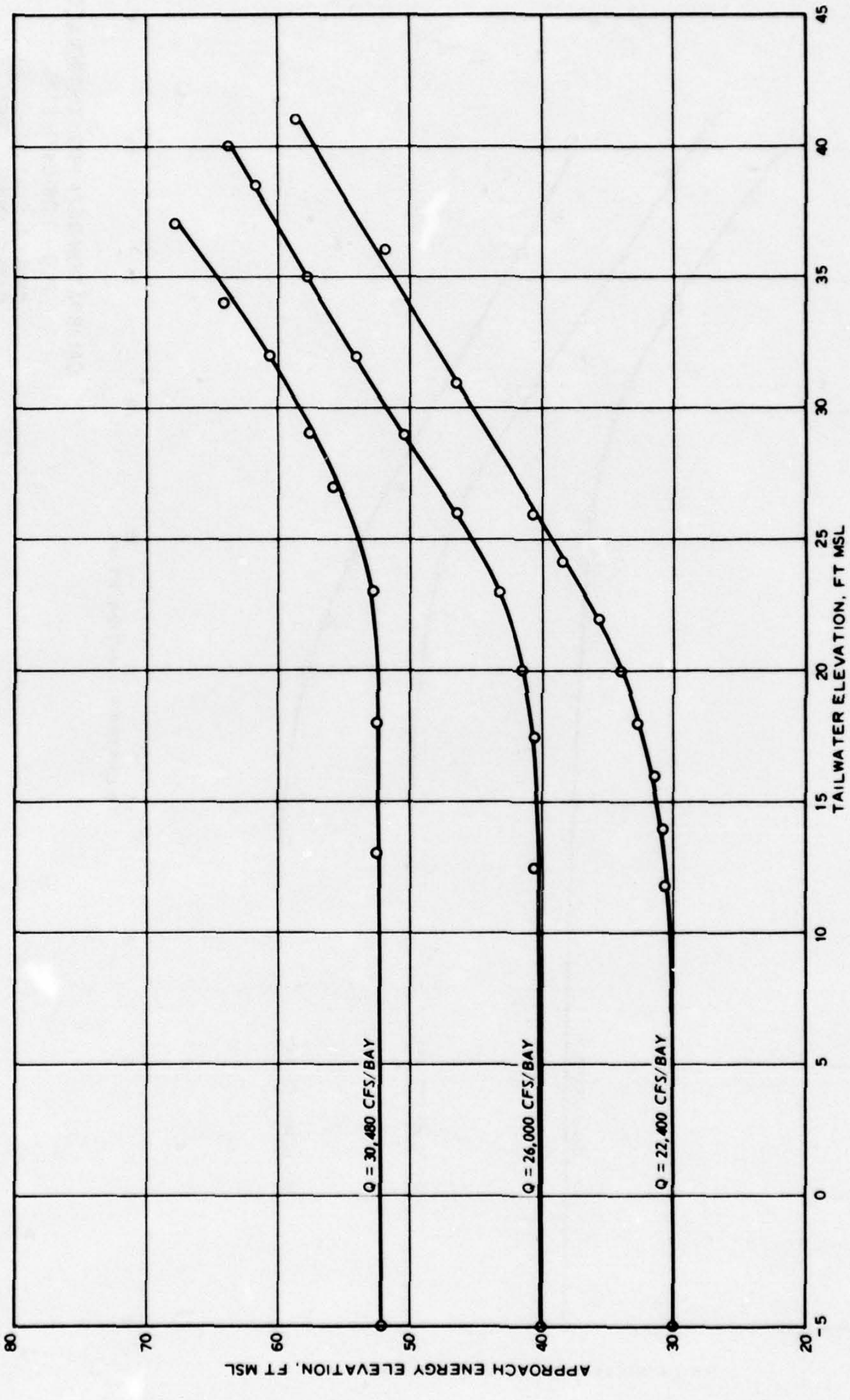
2 OF 2
ADA036996



END
DATE
FILMED
4-77

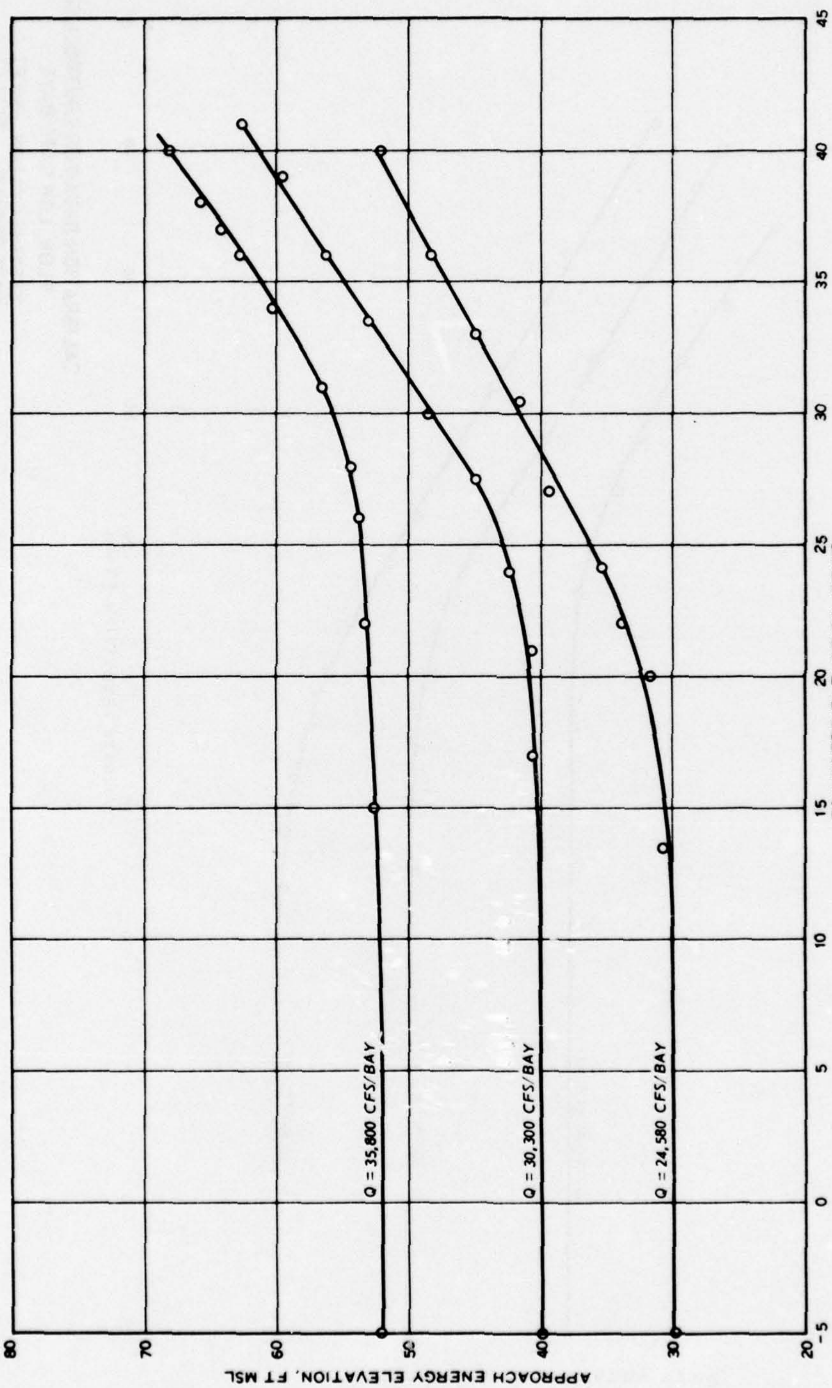


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAYS

CREST ELEVATION -5.0 FT
GATE OPENING 20.17 FT

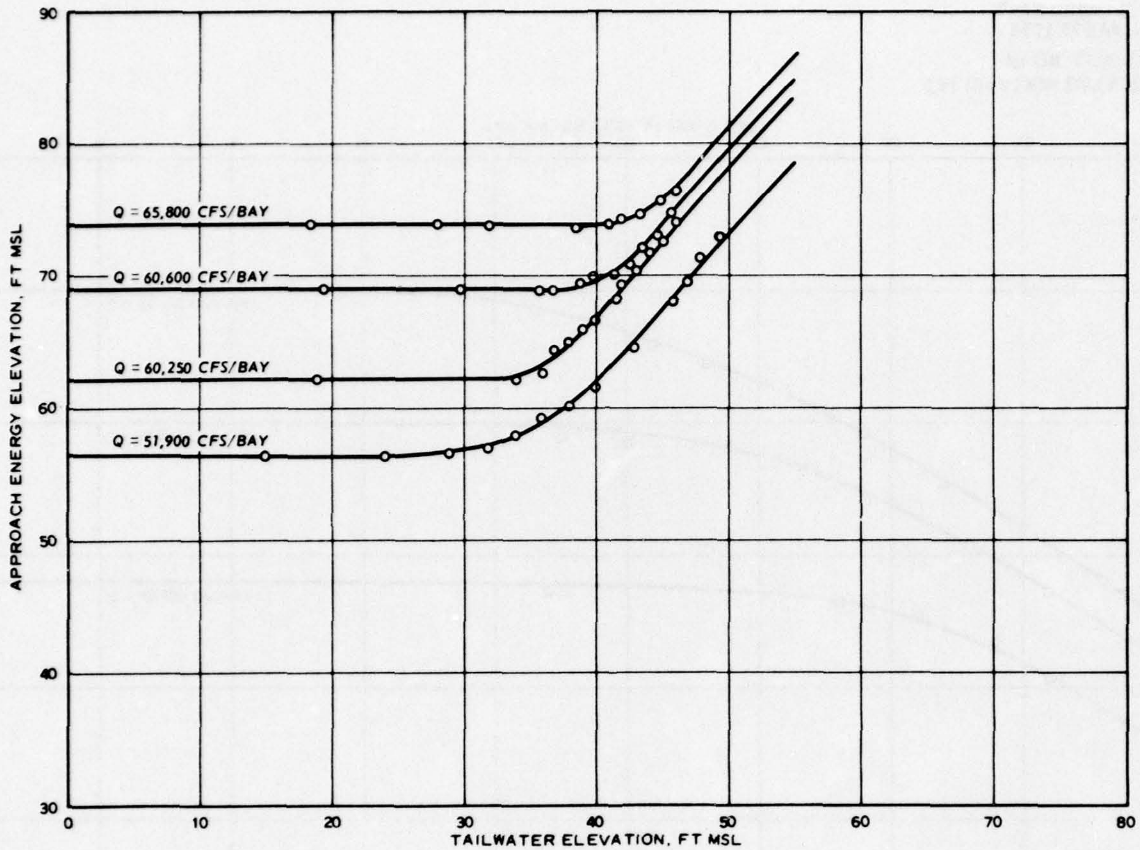


CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAYS

CREST ELEVATION -5.0 FT
GATE OPENING 24.75 FT

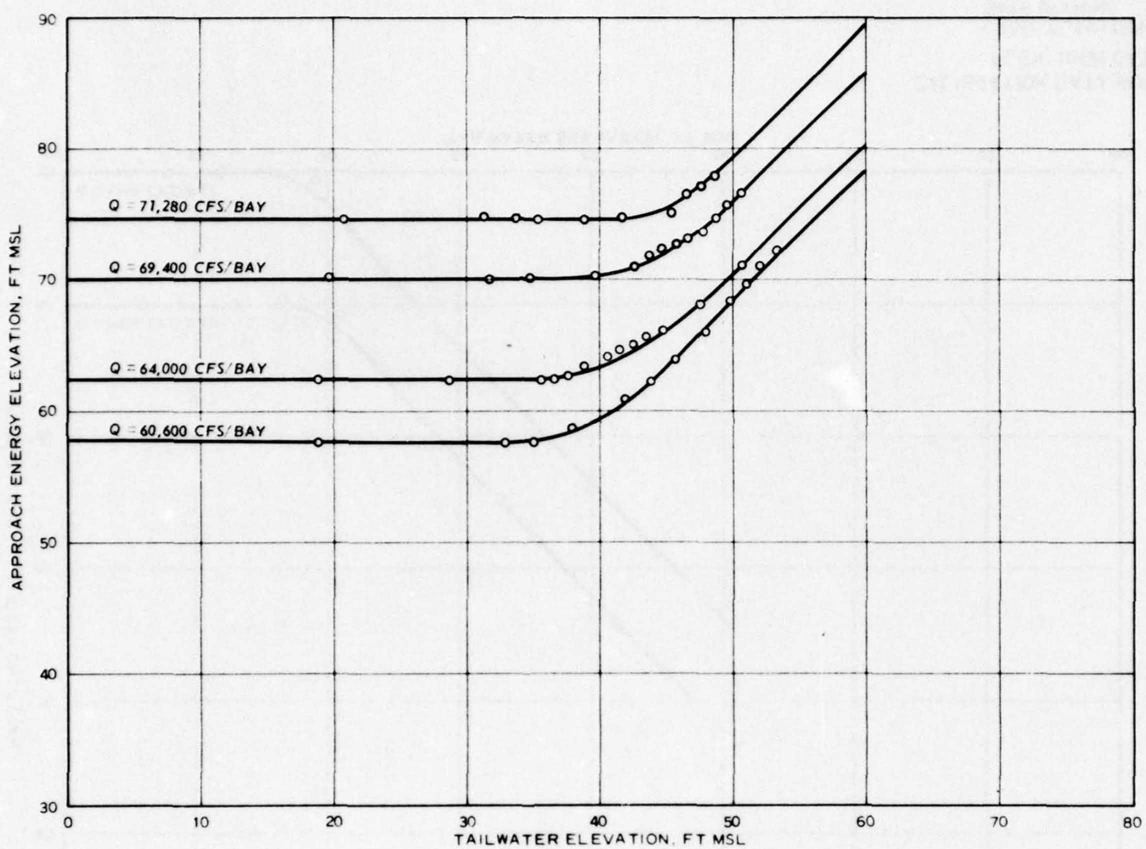
CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAYS

CREST ELEVATION -5.0 FT
GATE OPENING 28.83 FT



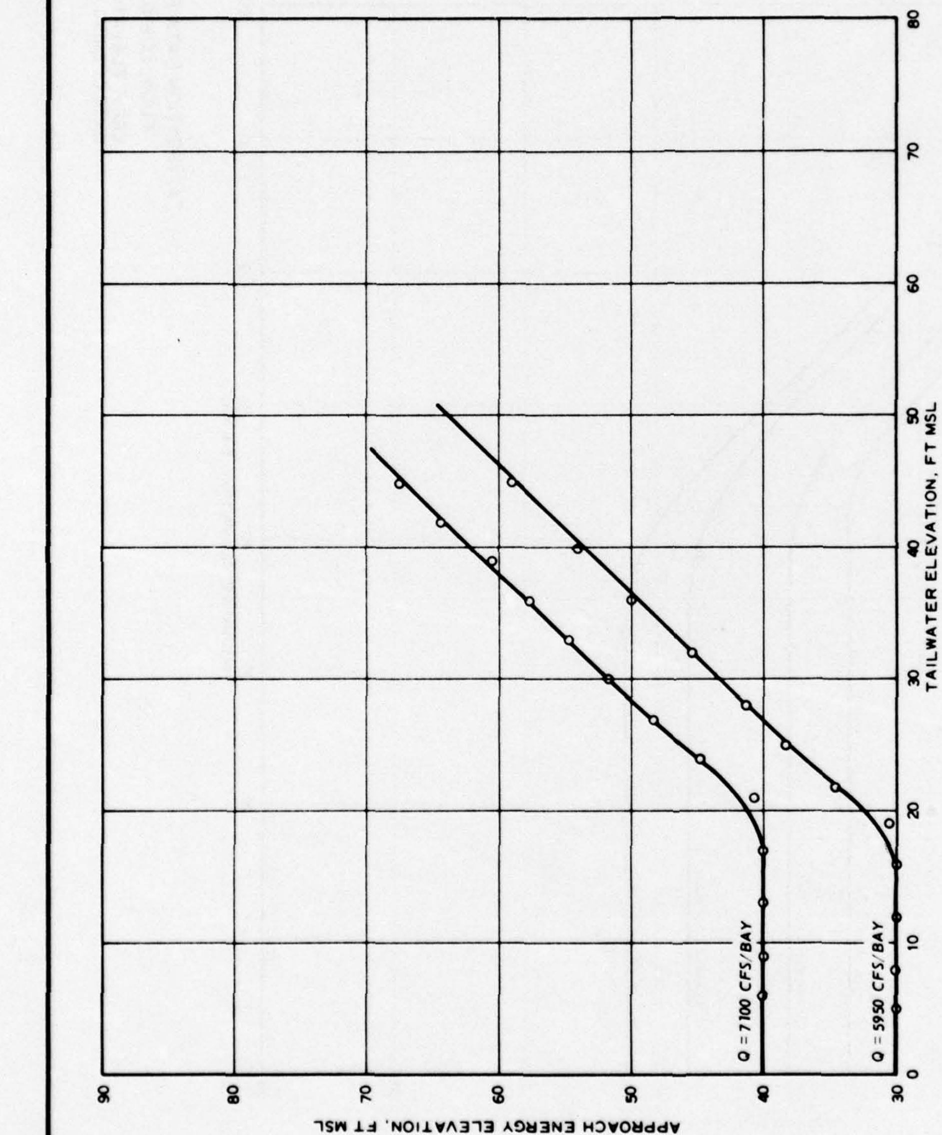
CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAYS

CREST ELEVATION -5.00 FT
GATE OPENING 36.19 FT



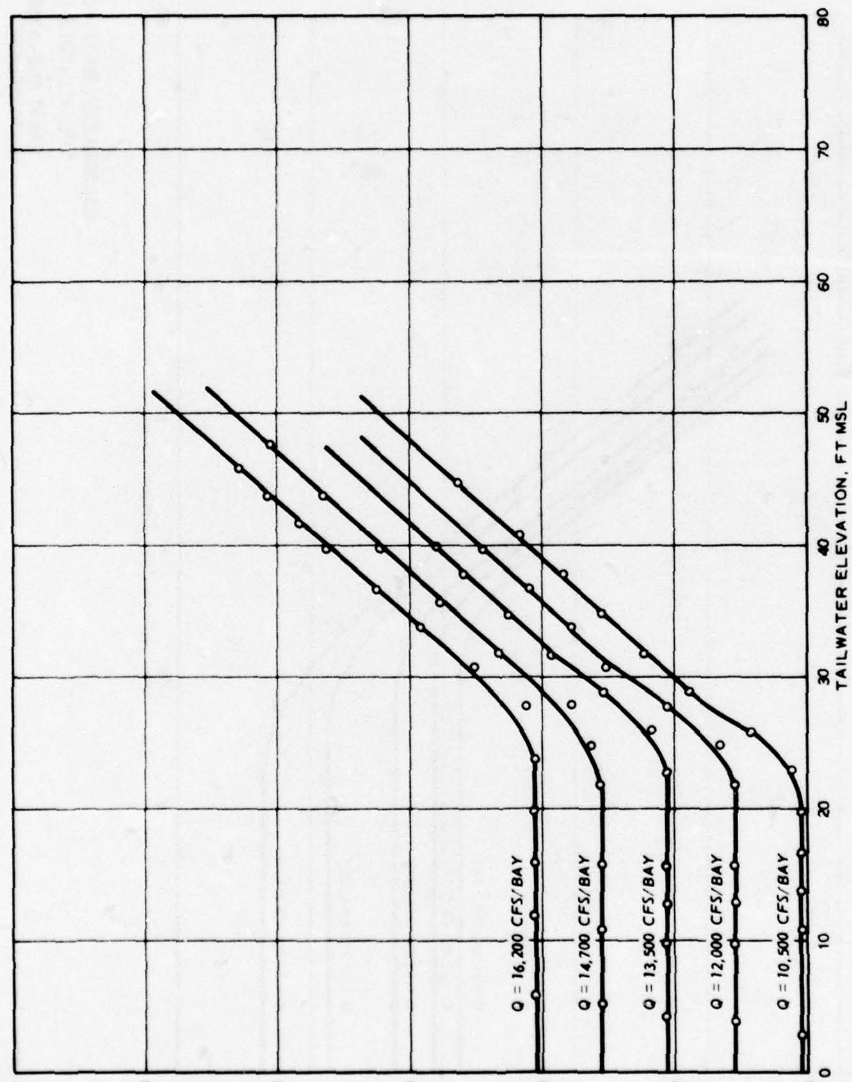
CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAYS

CREST ELEVATION -5.00 FT
GATE OPENING 43.53 FT



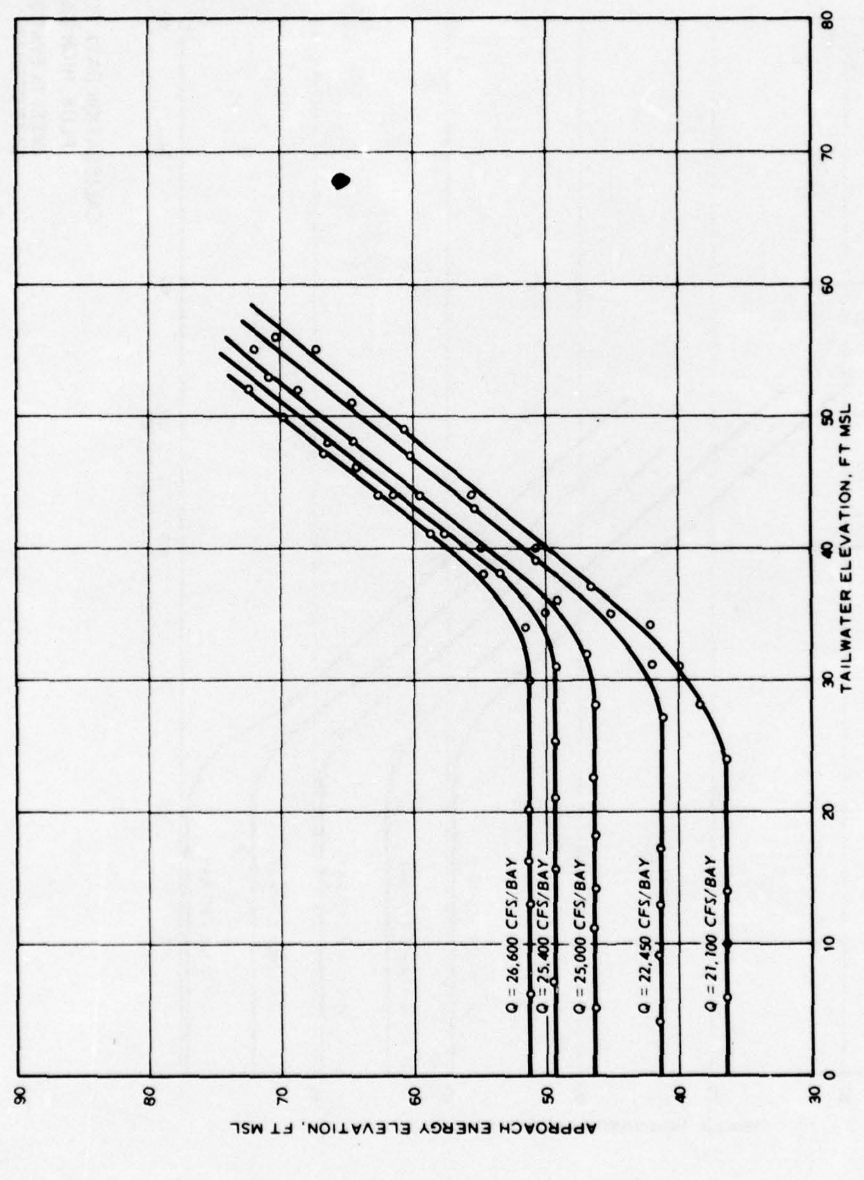
CALIBRATION DATA FOR CONTROLLED FLOW, HIGH GATE BAYS

CREST ELEVATION 10.00 FT
GATE OPENING 6.00 FT



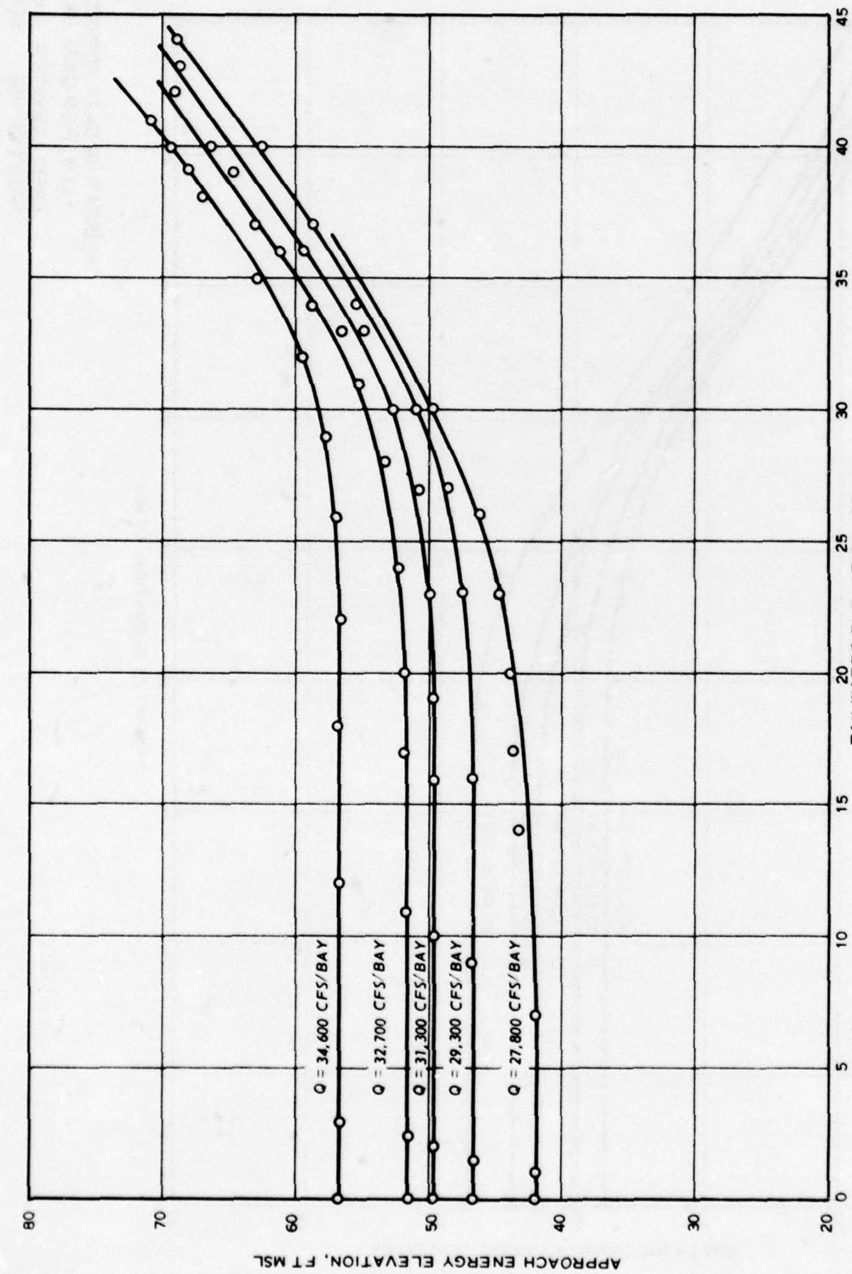
CALIBRATION DATA FOR CONTROLLED FLOW, HIGH GATE BAYS

CREST ELEVATION 10.00 FT
GATE OPENING 11.25 FT



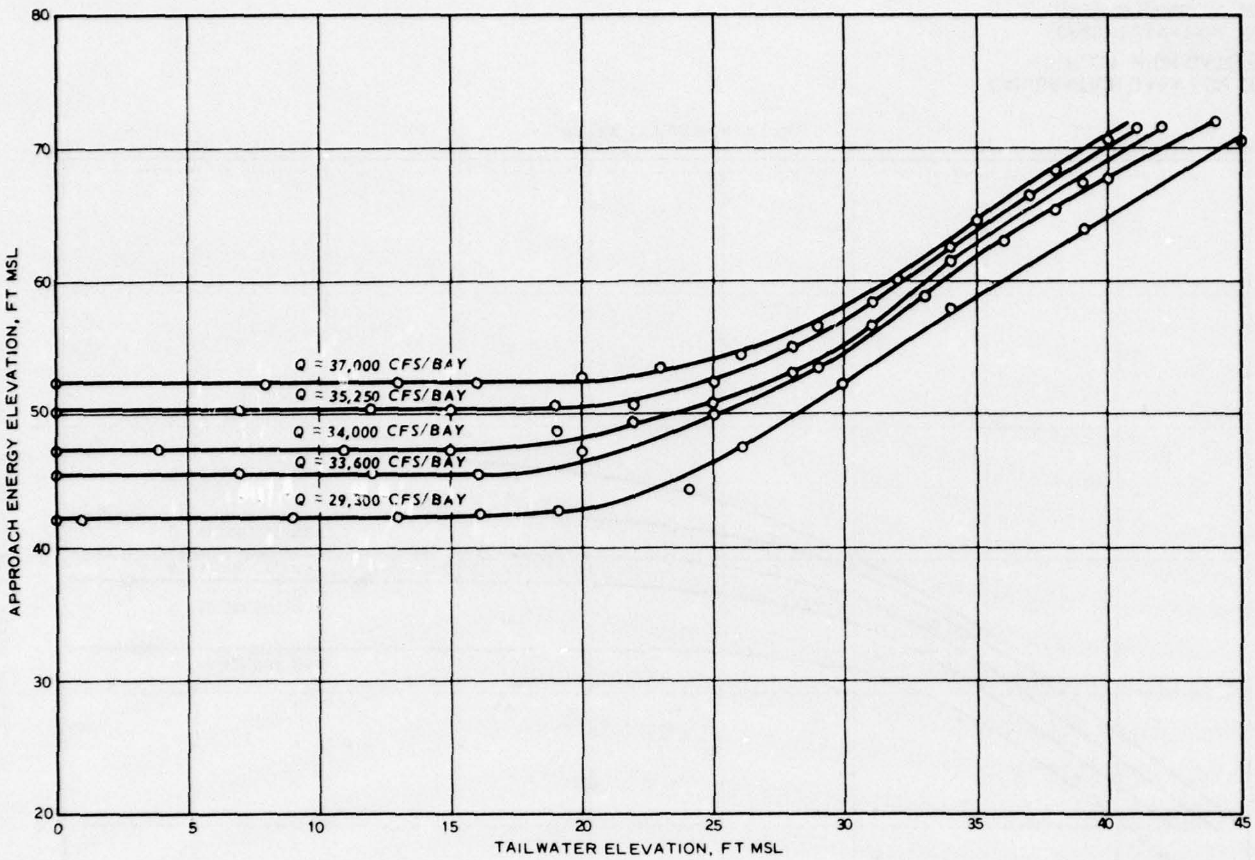
CALIBRATION DATA FOR CONTROLLED FLOW, HIGH GATE BAYS

CREST ELEVATION 10.00 FT
GATE OPENING 20.17 FT



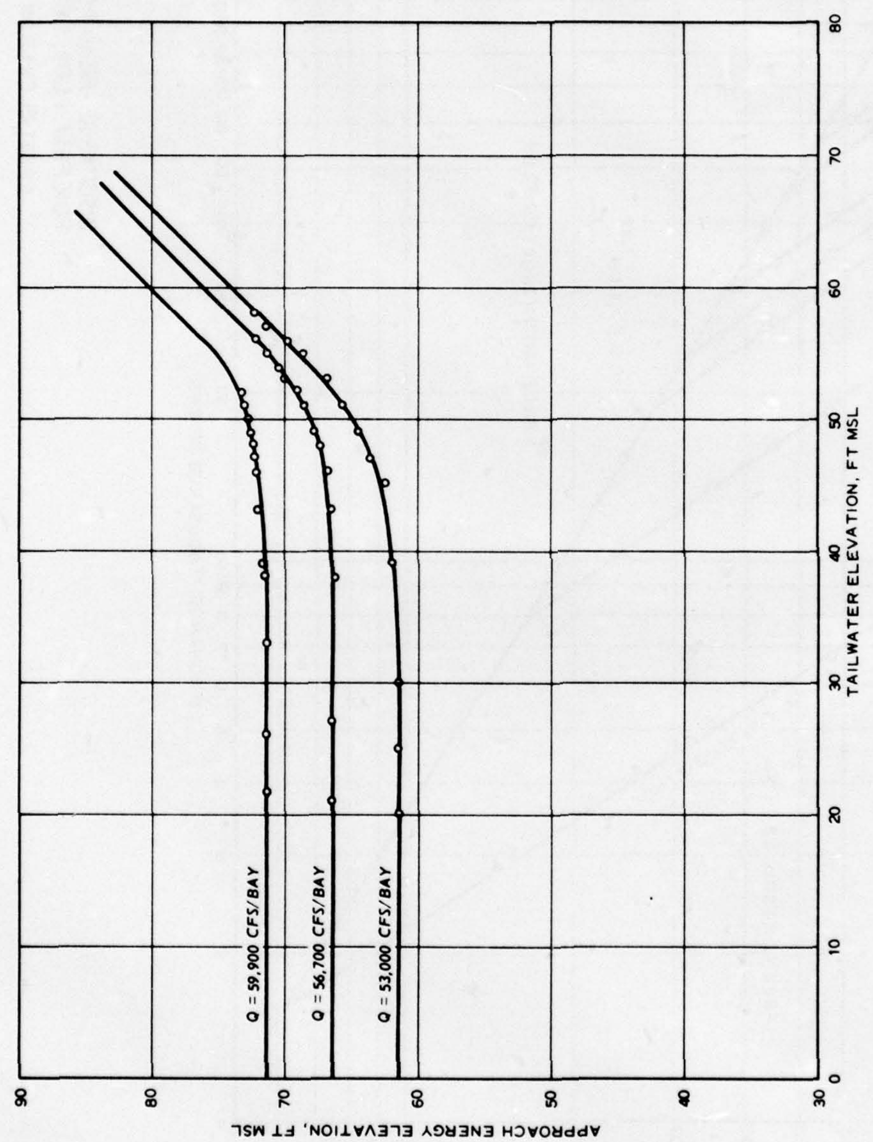
CALIBRATION DATA FOR CONTROLLED FLOW, HIGH GATE BAYS

CREST ELEVATION 10.00 FT
GATE OPENING 24.75 FT



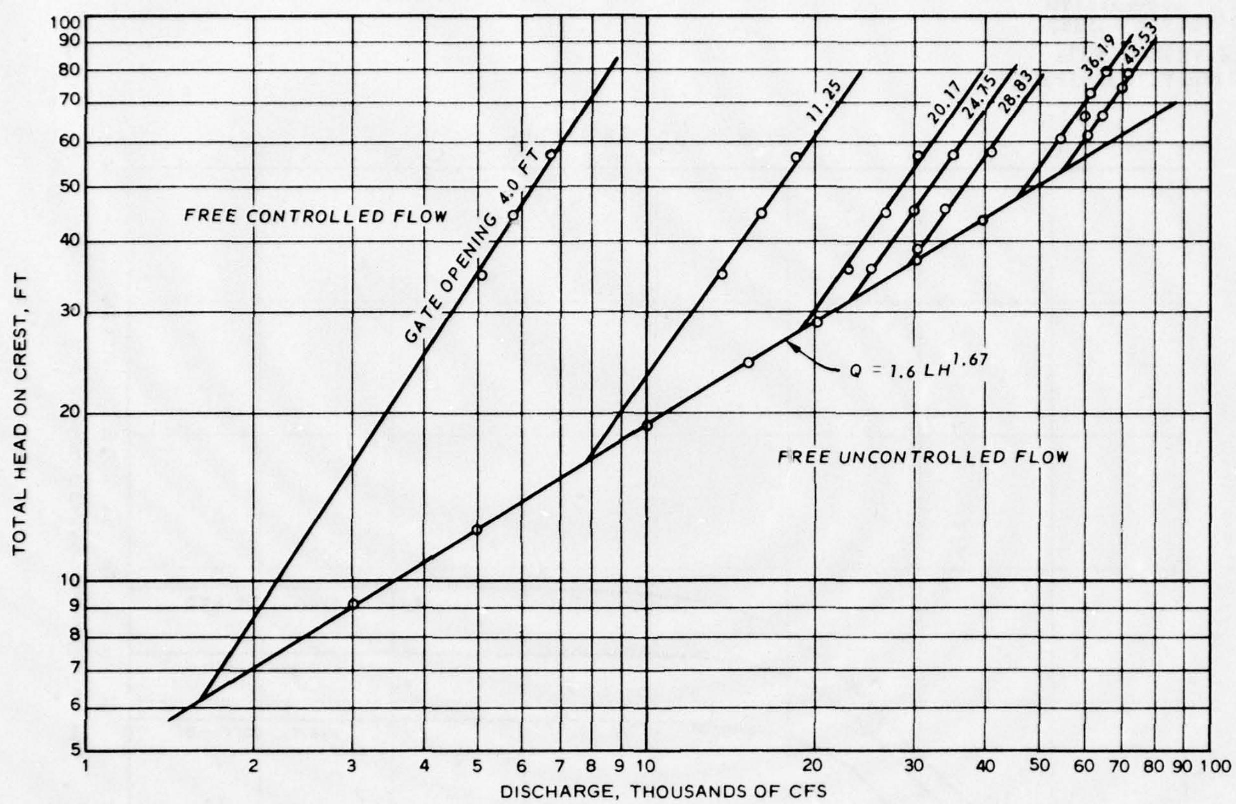
CALIBRATION DATA FOR CONTROLLED FLOW, HIGH GATE BAYS

CREST ELEVATION 10.00 FT
GATE OPENING 28.83 FT

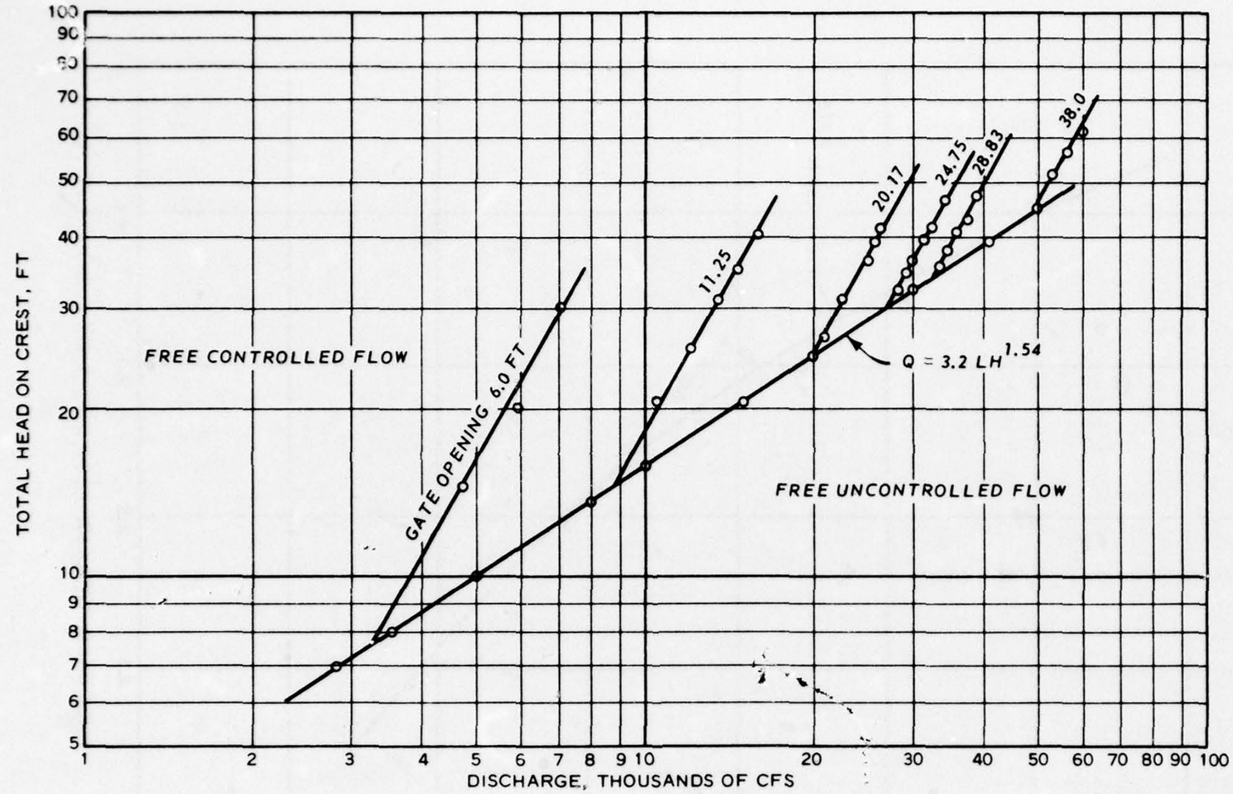


CALIBRATION DATA FOR CONTROLLED FLOW, HIGH GATE BAYS

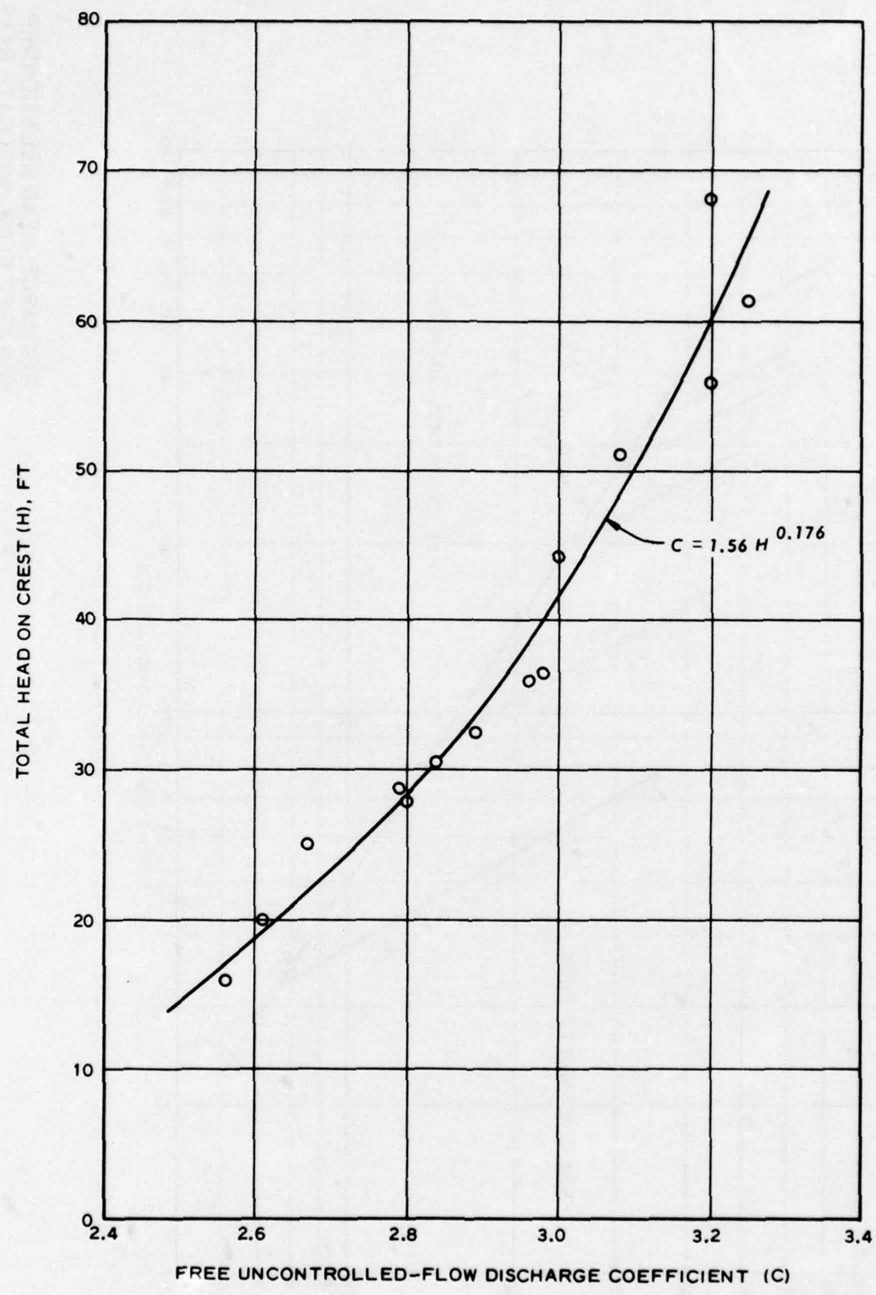
CREST ELEVATION 10.00 FT
GATE OPENING 38.00 FT



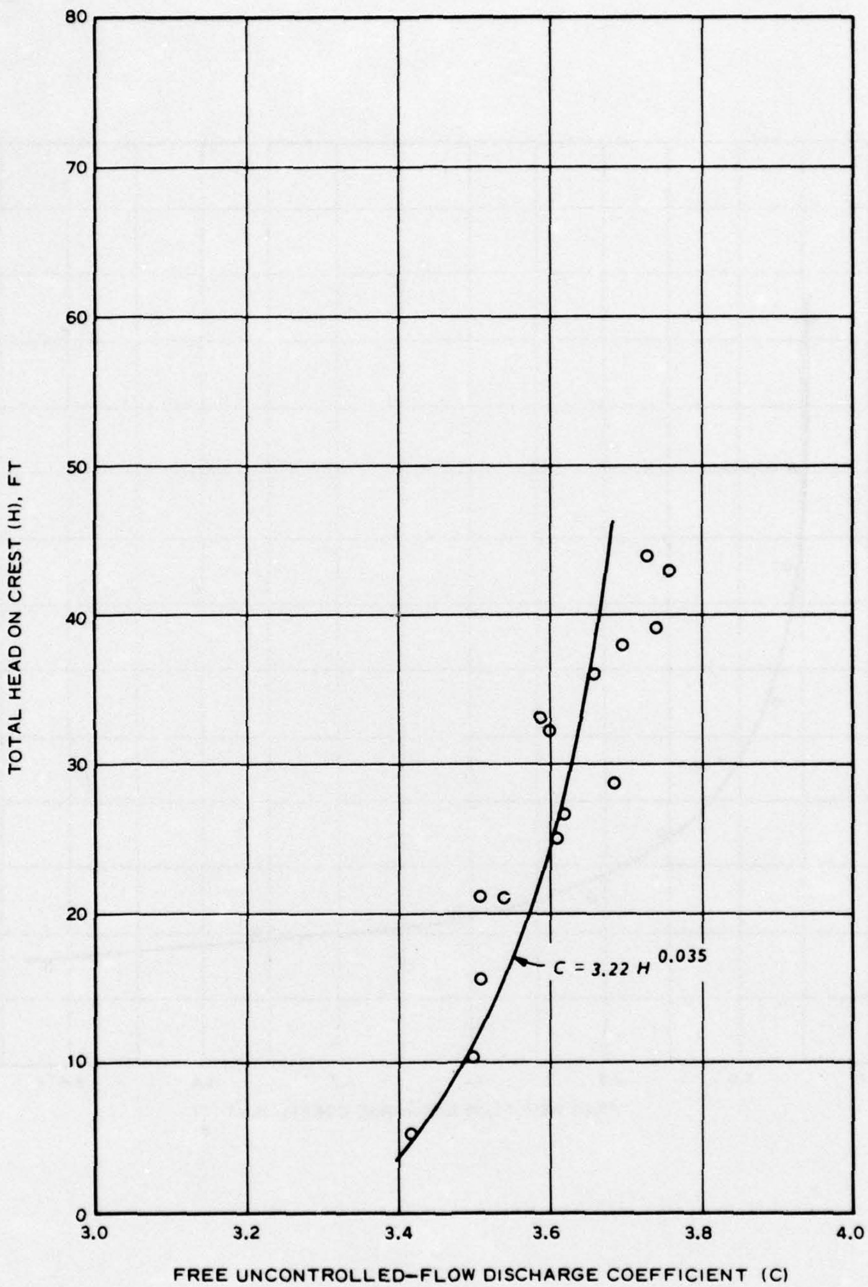
DISCHARGE - HEAD RELATIONSHIP
FOR FREE FLOW, LOW GATE BAYS
CREST ELEVATION -5.0 FT



DISCHARGE-HEAD RELATIONSHIP
FOR FREE FLOW, HIGH GATE BAYS
CREST ELEVATION 10.0 FT

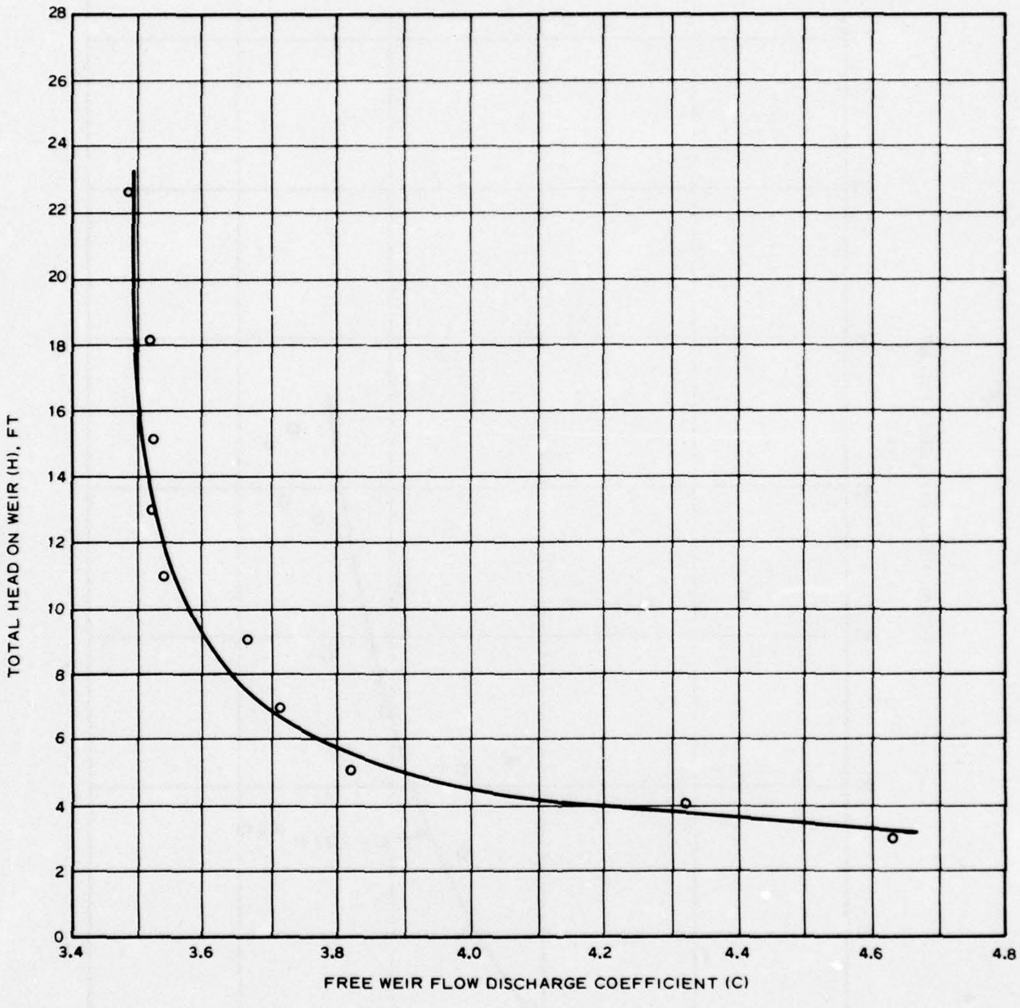


DISCHARGE COEFFICIENTS FOR FREE UNCONTROLLED FLOW, LOW GATE BAYS
CRREST ELEVATION -5.0 FT



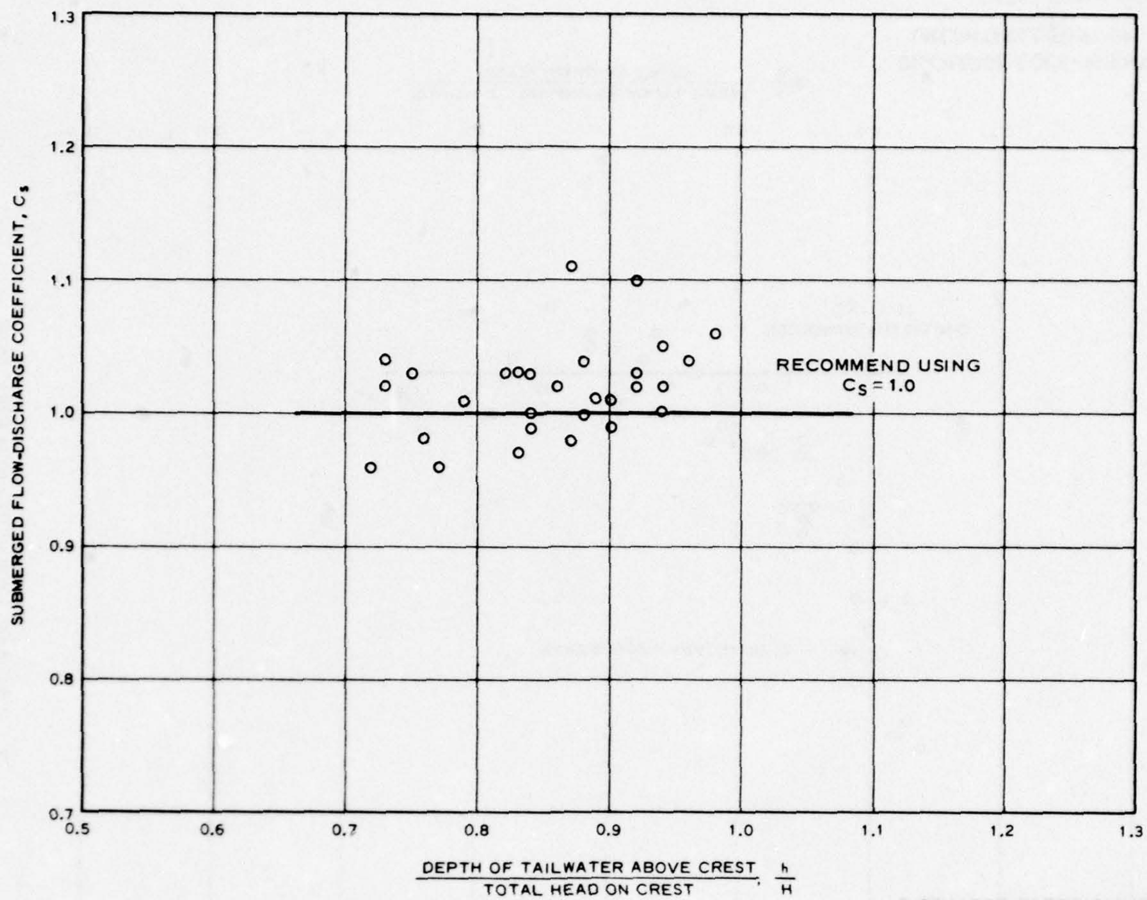
DISCHARGE COEFFICIENT FOR FREE UNCONTROLLED FLOW, HIGH GATE BAYS

CREST ELEVATION 10.0 FT



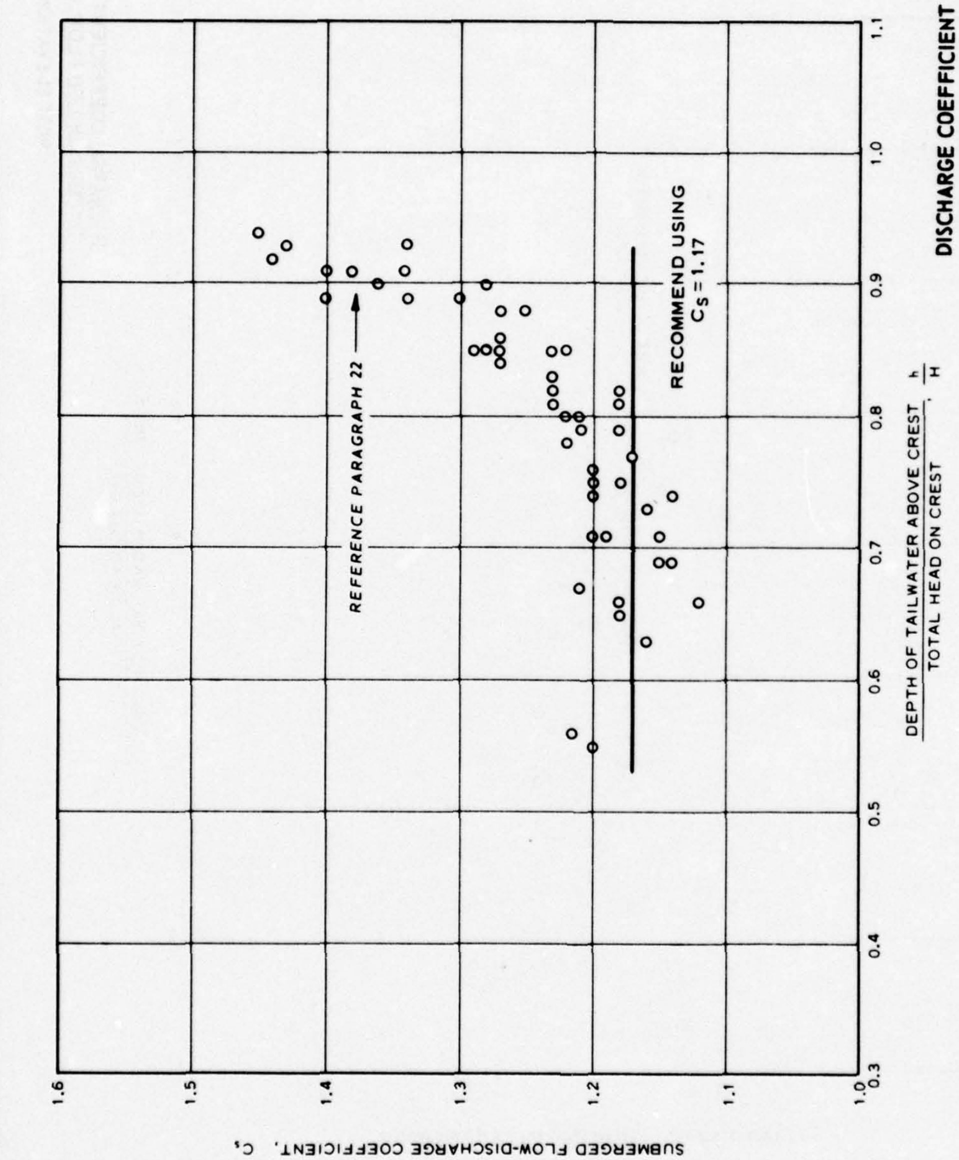
DISCHARGE COEFFICIENT FOR FREE WEIR FLOW, GATE LEAVES 4L & 3L IN LOW GATE BAYS

WEIR ELEVATION 29.0 FT



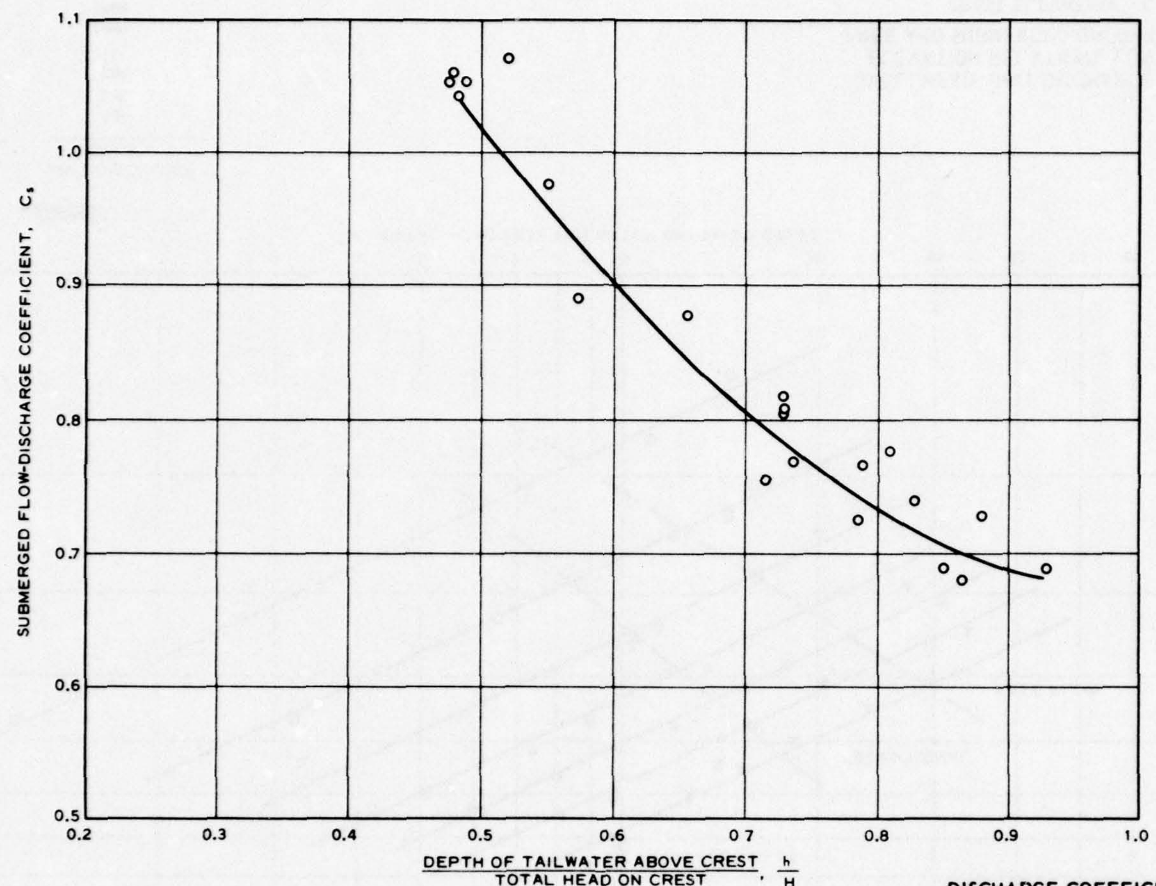
DISCHARGE COEFFICIENT FOR SUBMERGED UNCONTROLLED FLOW, LOW GATE BAYS

CREST ELEVATION -5.0 FT



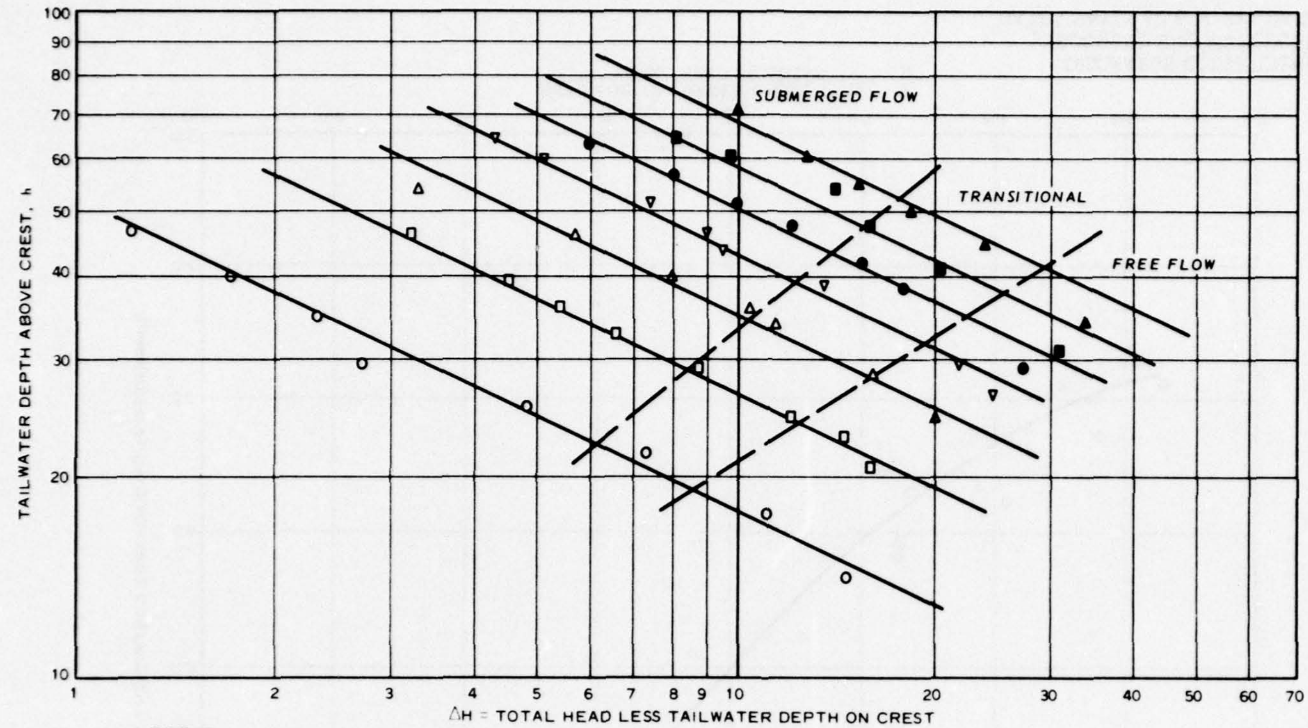
DISCHARGE COEFFICIENT FOR SUBMERGED UNCONTROLLED FLOW, HIGH GATE BAYS

CREST ELEVATION 10.0 FT



DISCHARGE COEFFICIENT FOR
SUBMERGED UNCONTROLLED FLOW
GATE LEAVES 4L & 3L IN LOW GATE BAYS

WEIR ELEVATION 29.0 FT

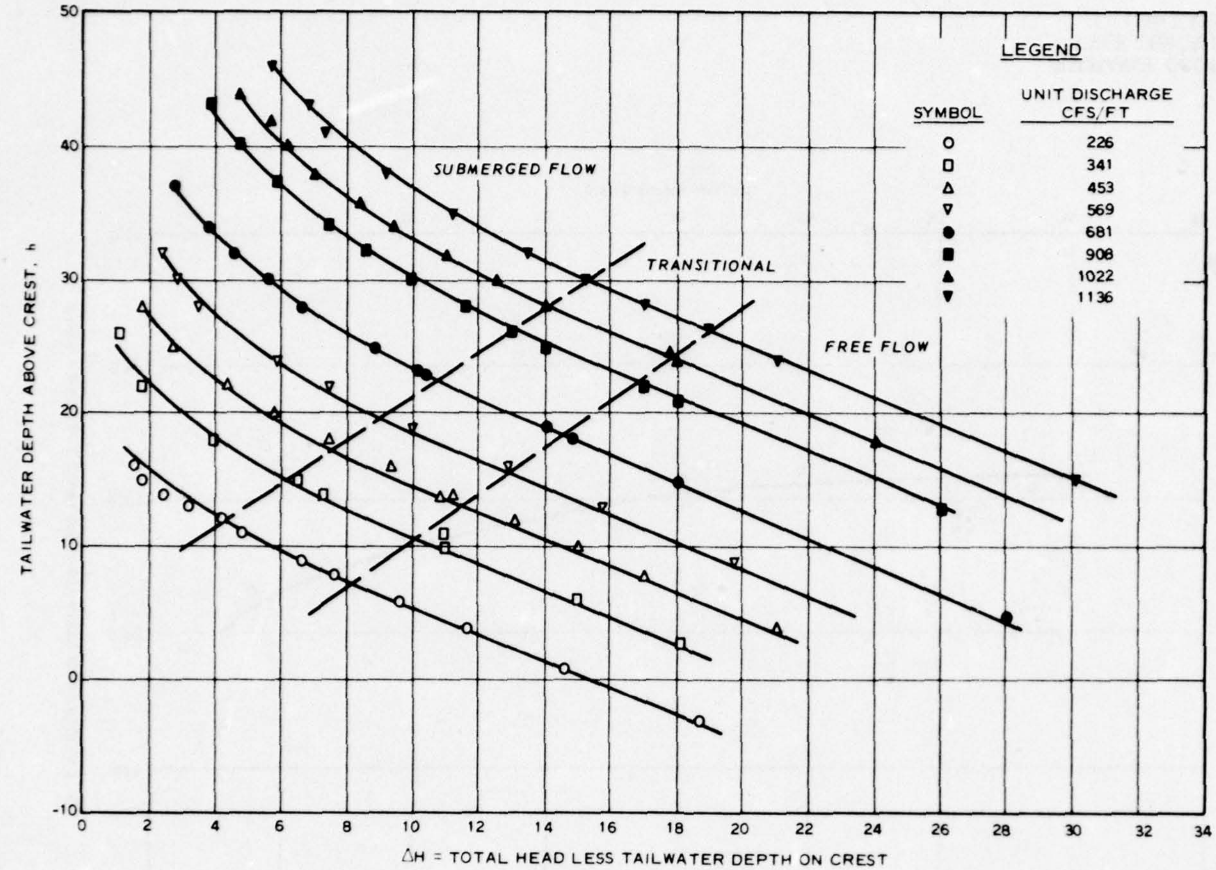


LEGEND

SYMBOL	UNIT DISCHARGE CFS/FT
○	432
□	659
△	886
▽	1113
●	1340
■	1568
▲	1795

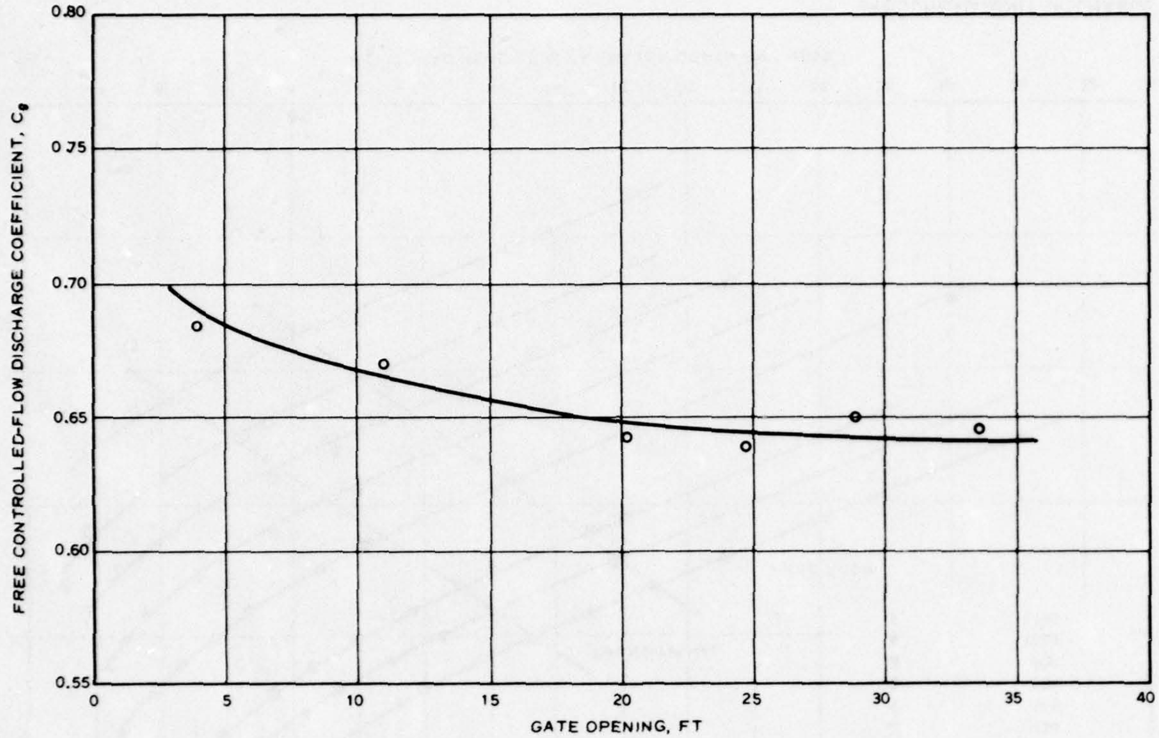
SWELLHEAD - UNIT DISCHARGE - TAILWATER
ELEVATION RELATIONS, LOW GATE BAYS
FREE AND SUBMERGED UNCONTROLLED FLOW

CREST ELEVATION -5.0 FT

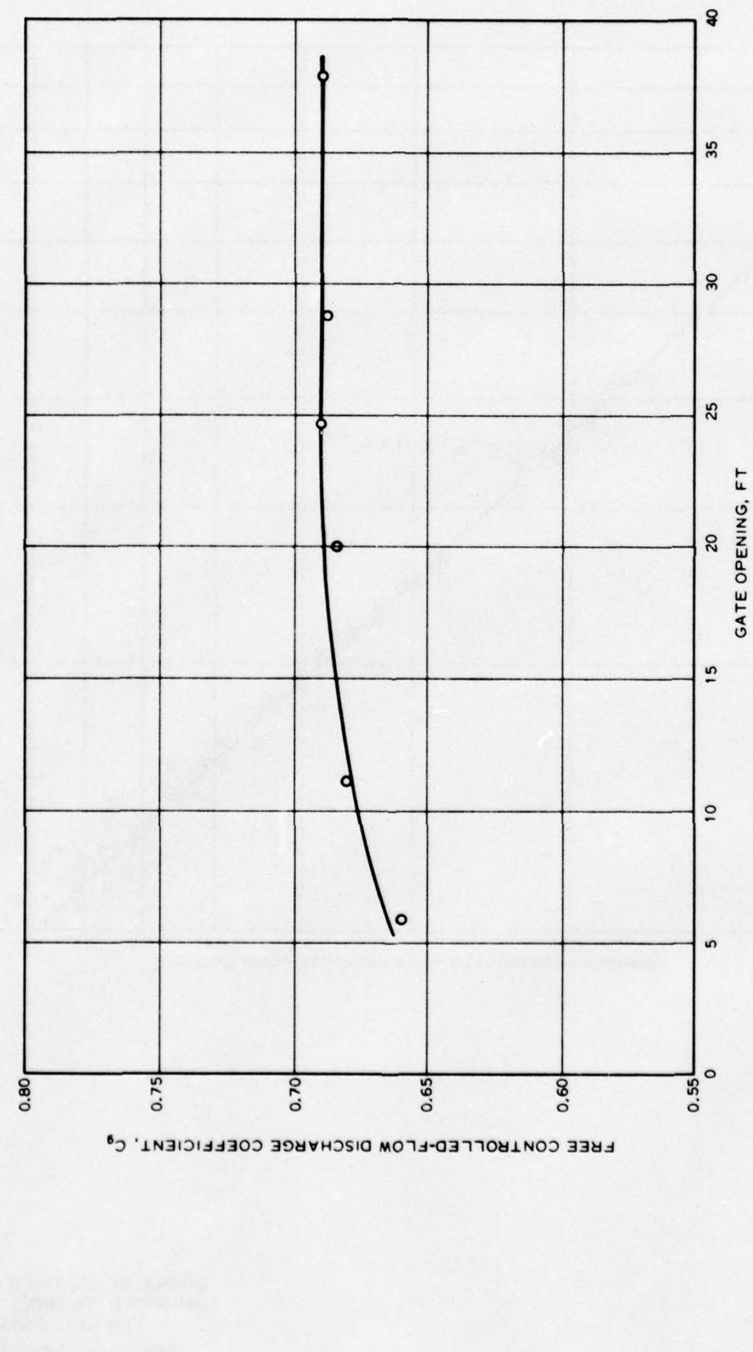


SWELLHEAD - UNIT DISCHARGE - TAILWATER ELEVATION RELATIONS, HIGH GATE BAYS FREE AND SUBMERGED UNCONTROLLED FLOW

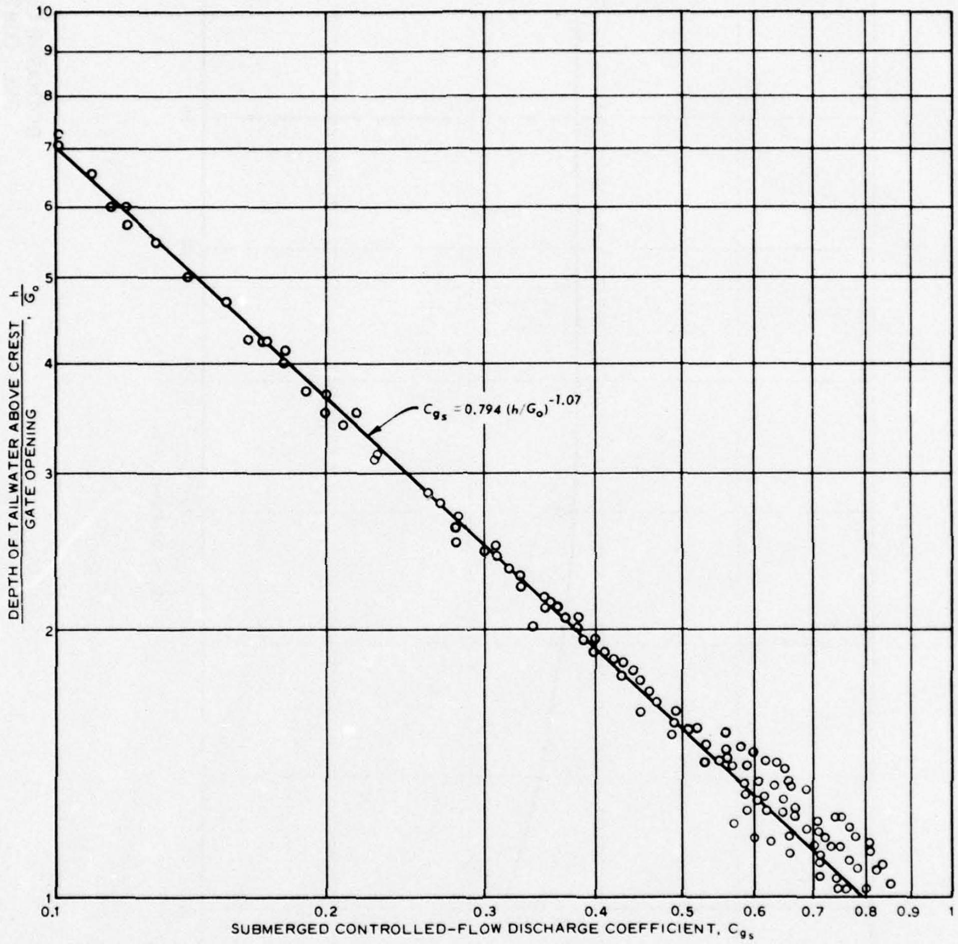
CREST ELEVATION 10.0 FT



DISCHARGE COEFFICIENTS FOR
FREE CONTROLLED FLOW
LOW GATE BAYS

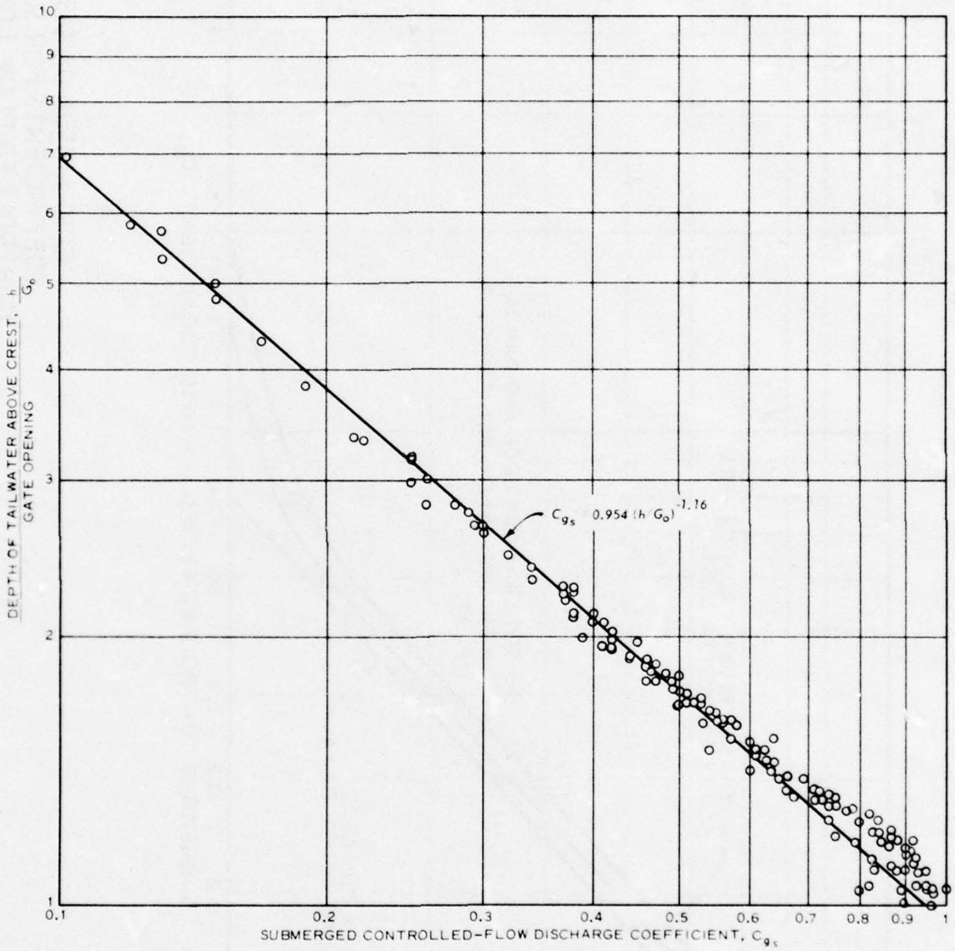


DISCHARGE COEFFICIENTS FOR FREE CONTROLLED FLOW HIGH GATE BAYS



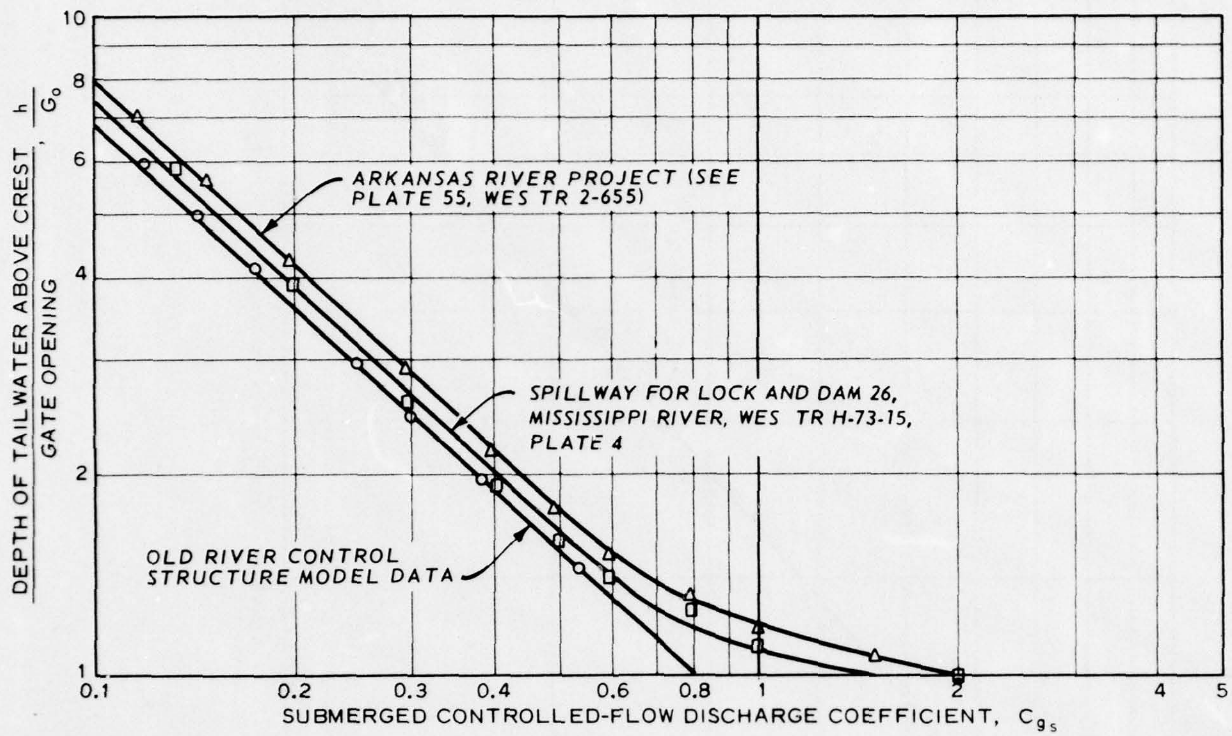
DISCHARGE COEFFICIENT FOR
SUBMERGED CONTROLLED FLOW
LOW GATE BAYS

CREST ELEVATION -5.0 FT

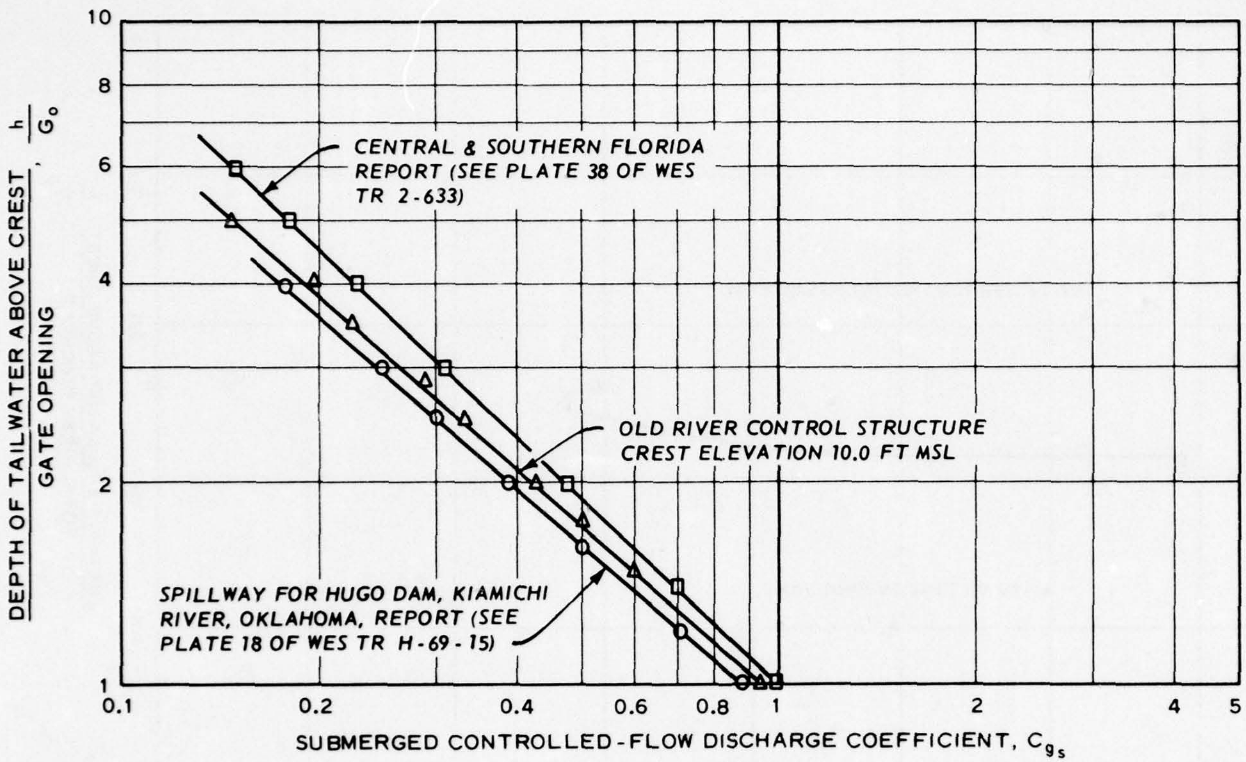


DISCHARGE COEFFICIENT FOR
SUBMERGED CONTROLLED FLOW
HIGH GATE BAYS

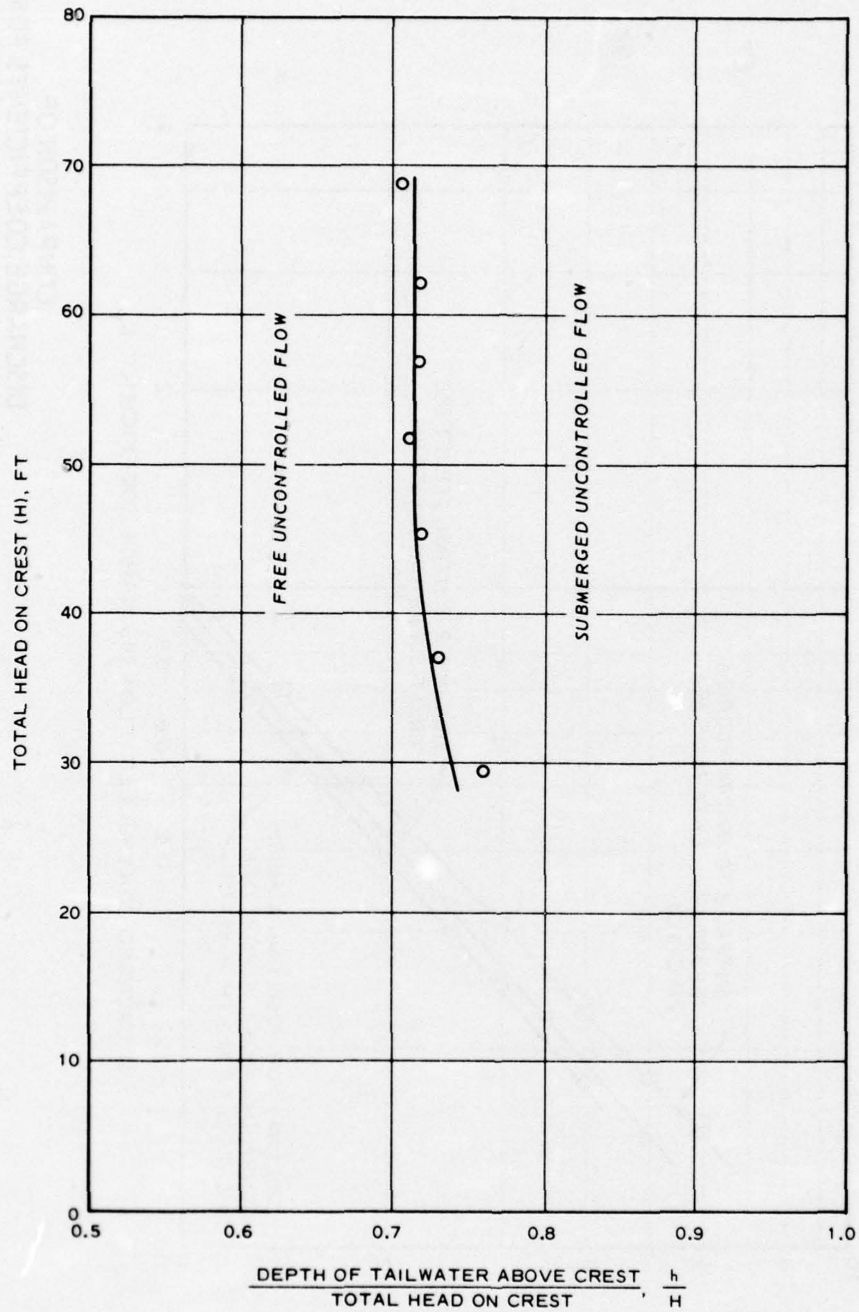
CREST ELEVATION 10.0 FT



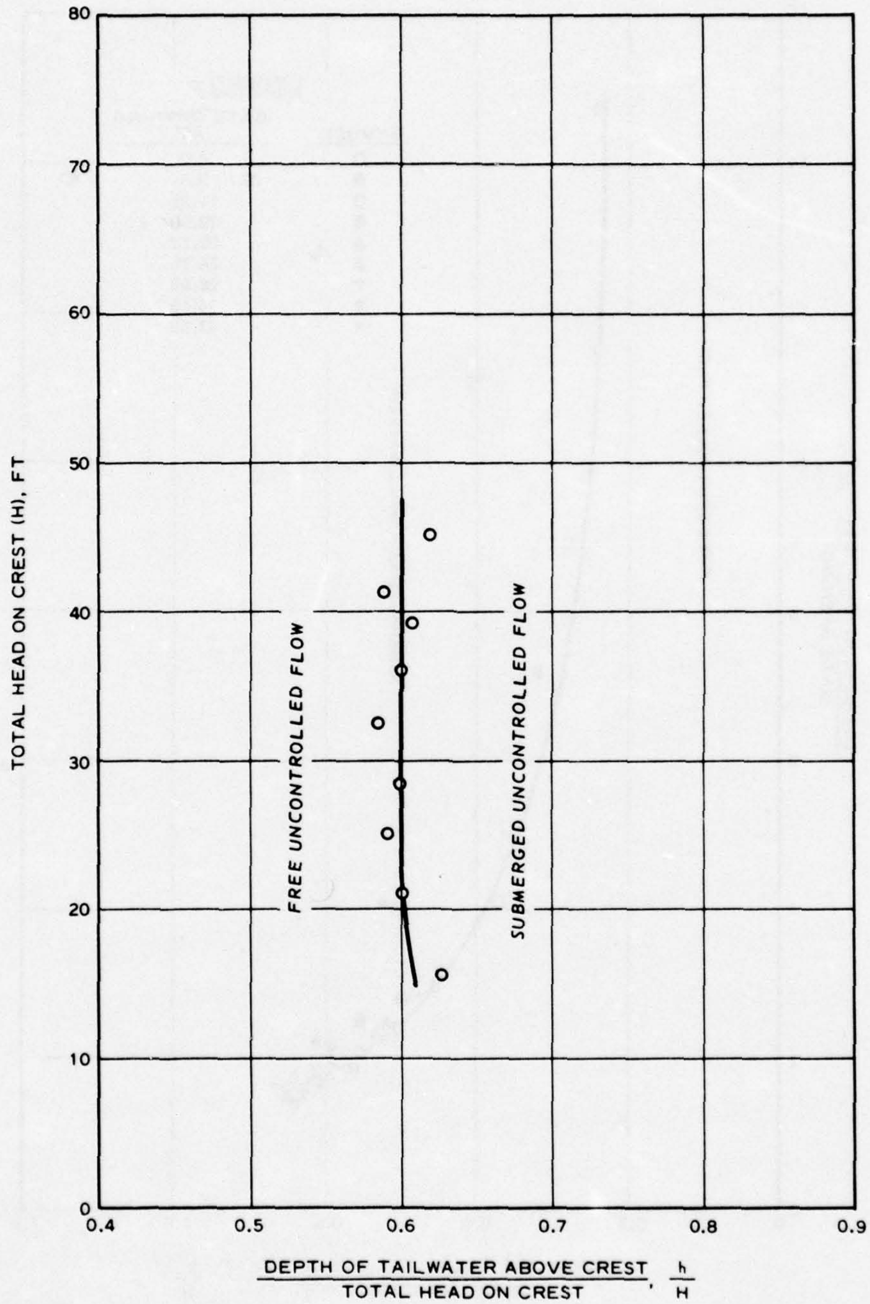
COMPARISON OF DISCHARGE COEFFICIENTS FOR SUBMERGED CONTROLLED FLOW, LOW GATE BAYS



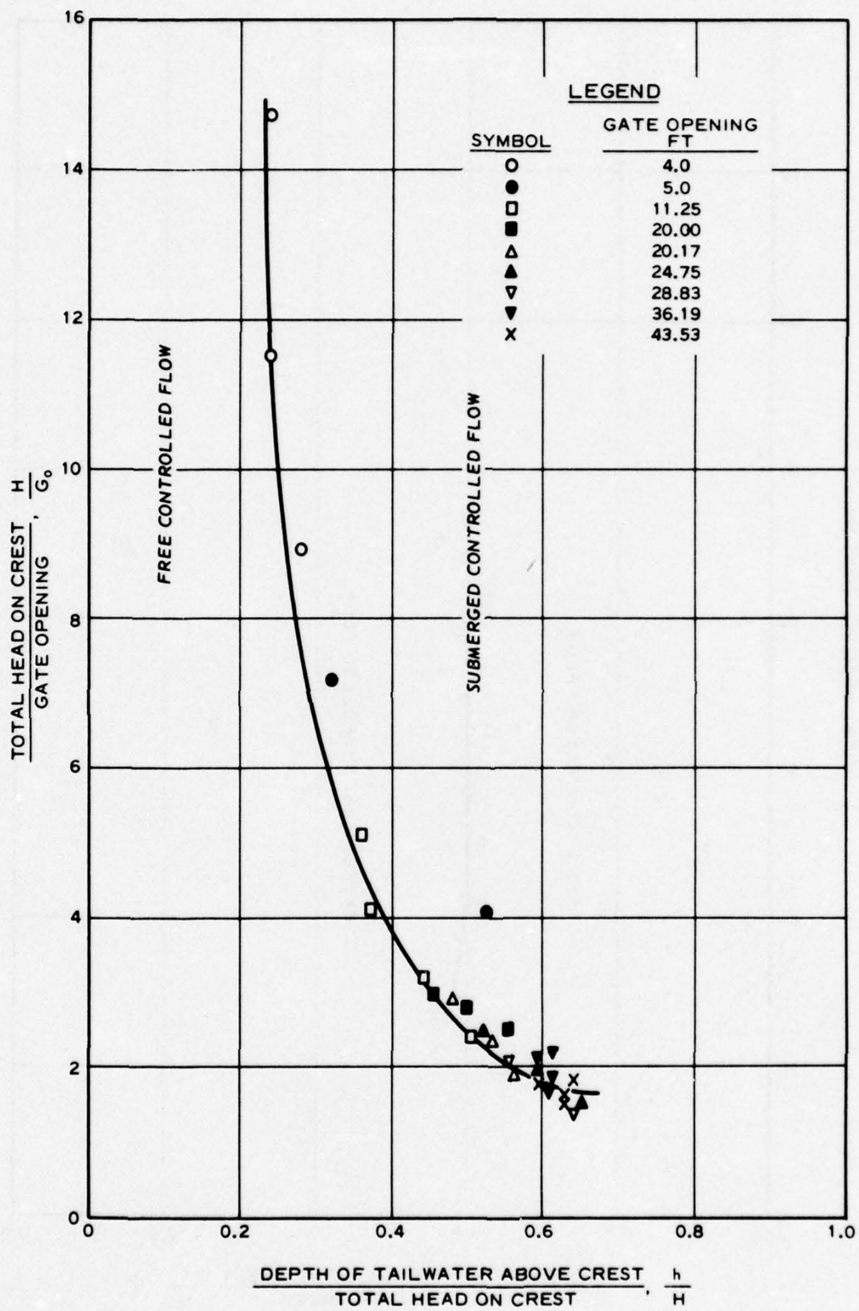
COMPARISON OF
DISCHARGE COEFFICIENTS FOR
SUBMERGED CONTROLLED FLOW
HIGH GATE BAYS



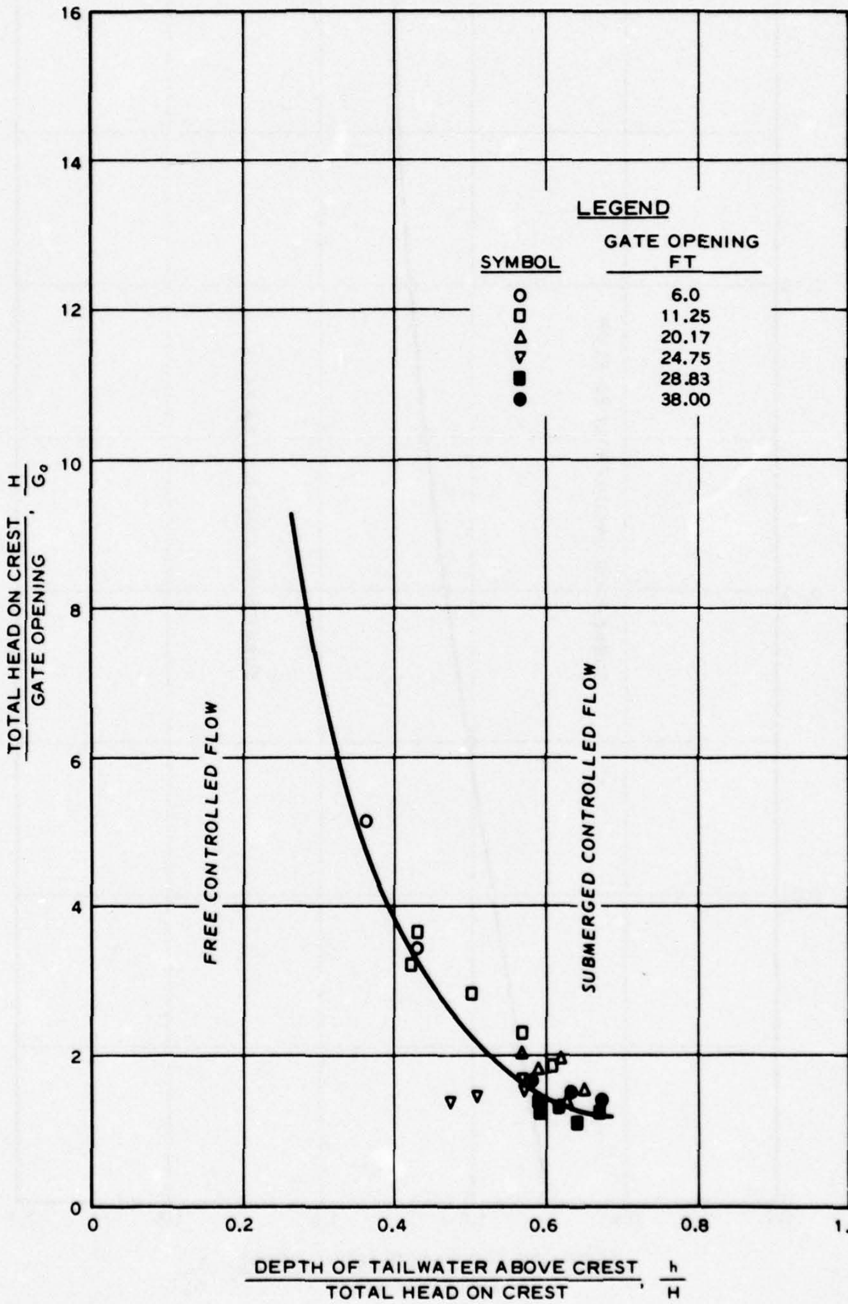
UNCONTROLLED-FLOW REGIMES
LOW GATE BAYS



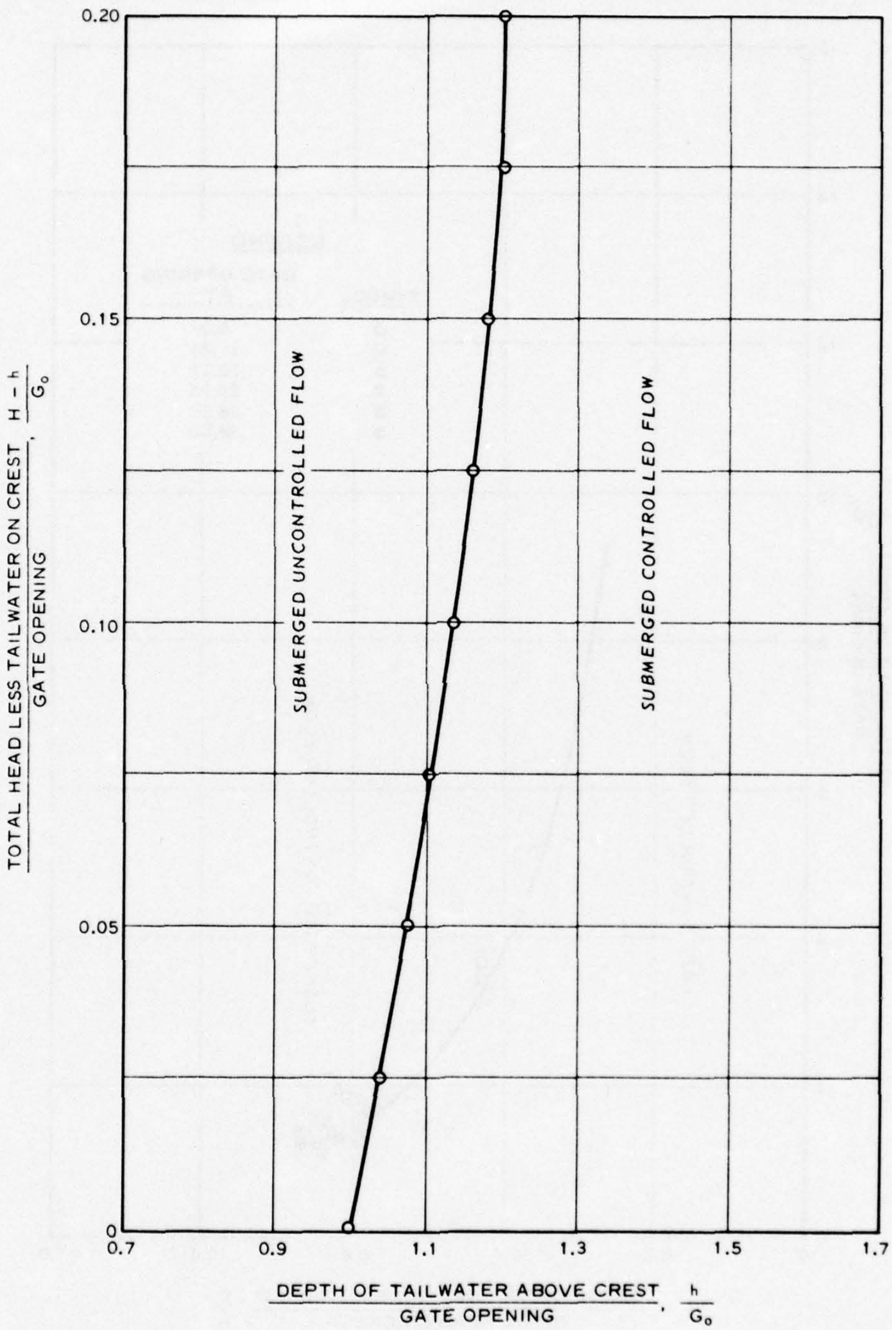
UNCONTROLLED-FLOW REGIMES
HIGH GATE BAYS



CONTROLLED-FLOW REGIMES
LOW GATE BAYS

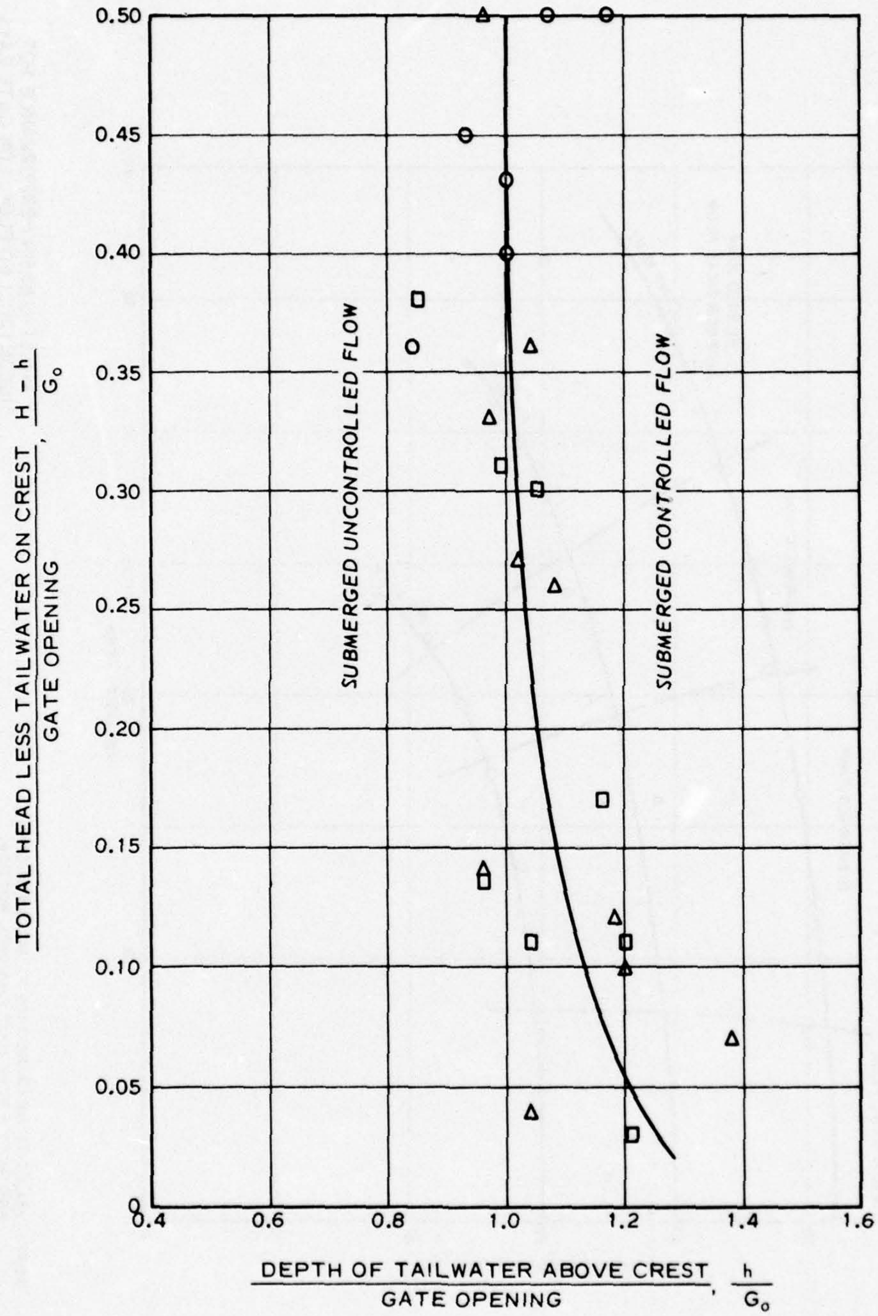


CONTROLLED-FLOW REGIMES
HIGH GATE BAYS



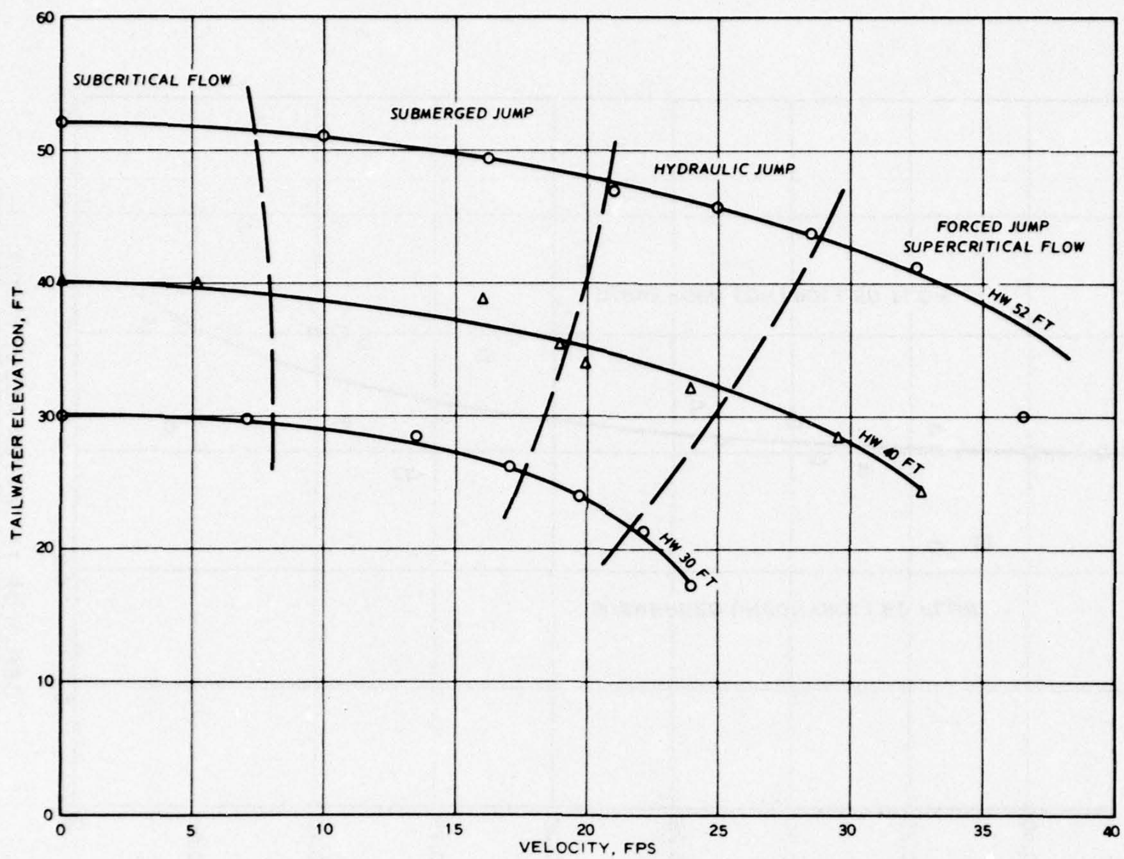
NOTE: DATA OBTAINED FROM TR 2-655, SEP 1964

SUBMERGED-FLOW REGIMES
LOW GATE BAYS



NOTE: DATA OBTAINED FROM TR 2-633, SEP 1963

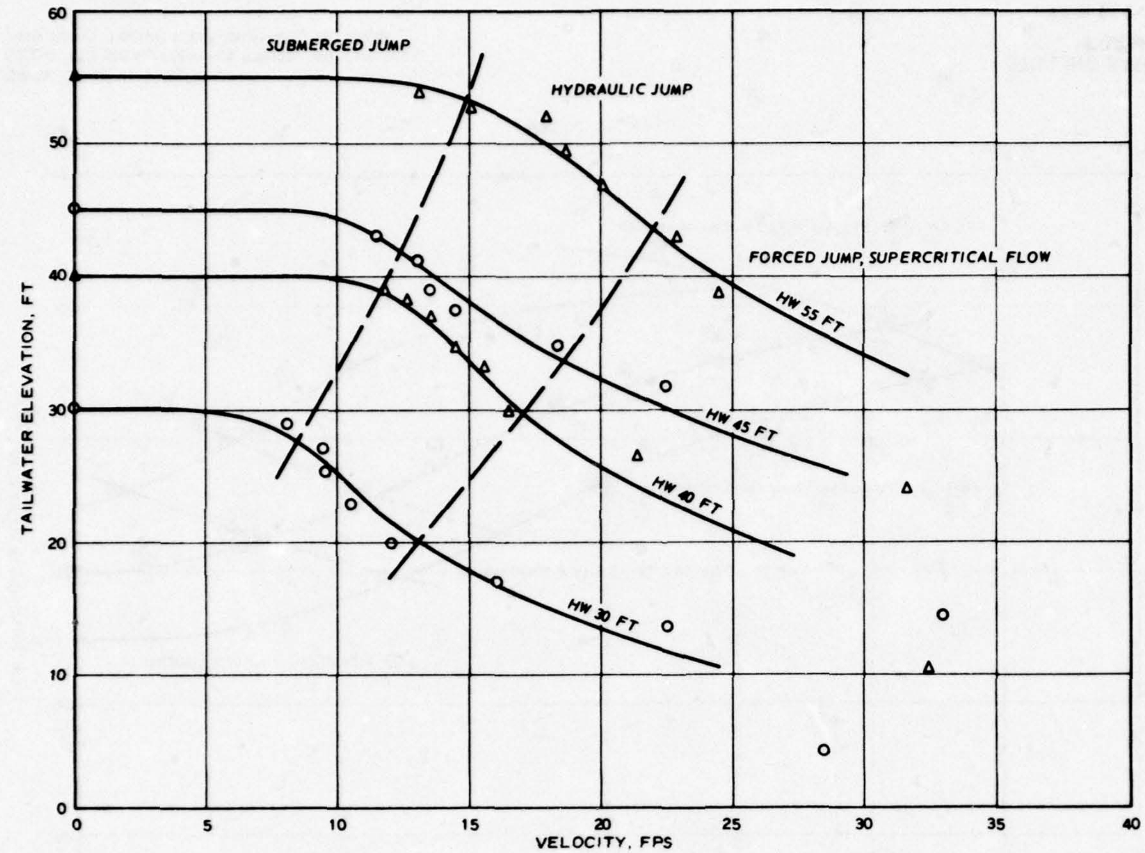
SUBMERGED - FLOW REGIMES
HIGH GATE BAYS



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE EXIT CHANNEL BOTTOM.

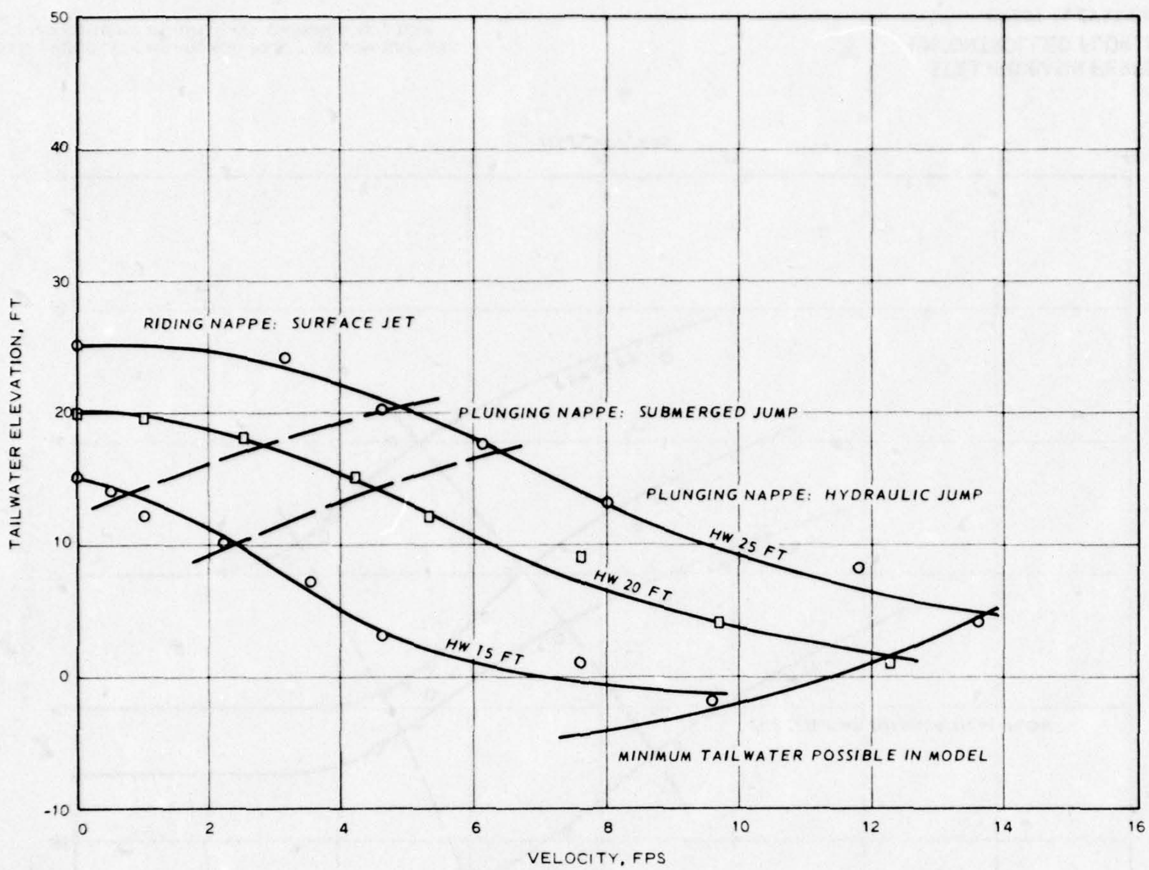
STILLING BASIN PERFORMANCE FOR UNCONTROLLED FLOW, LOW GATE BAYS

CRUST ELEVATION -5.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE EXIT CHANNEL BOTTOM

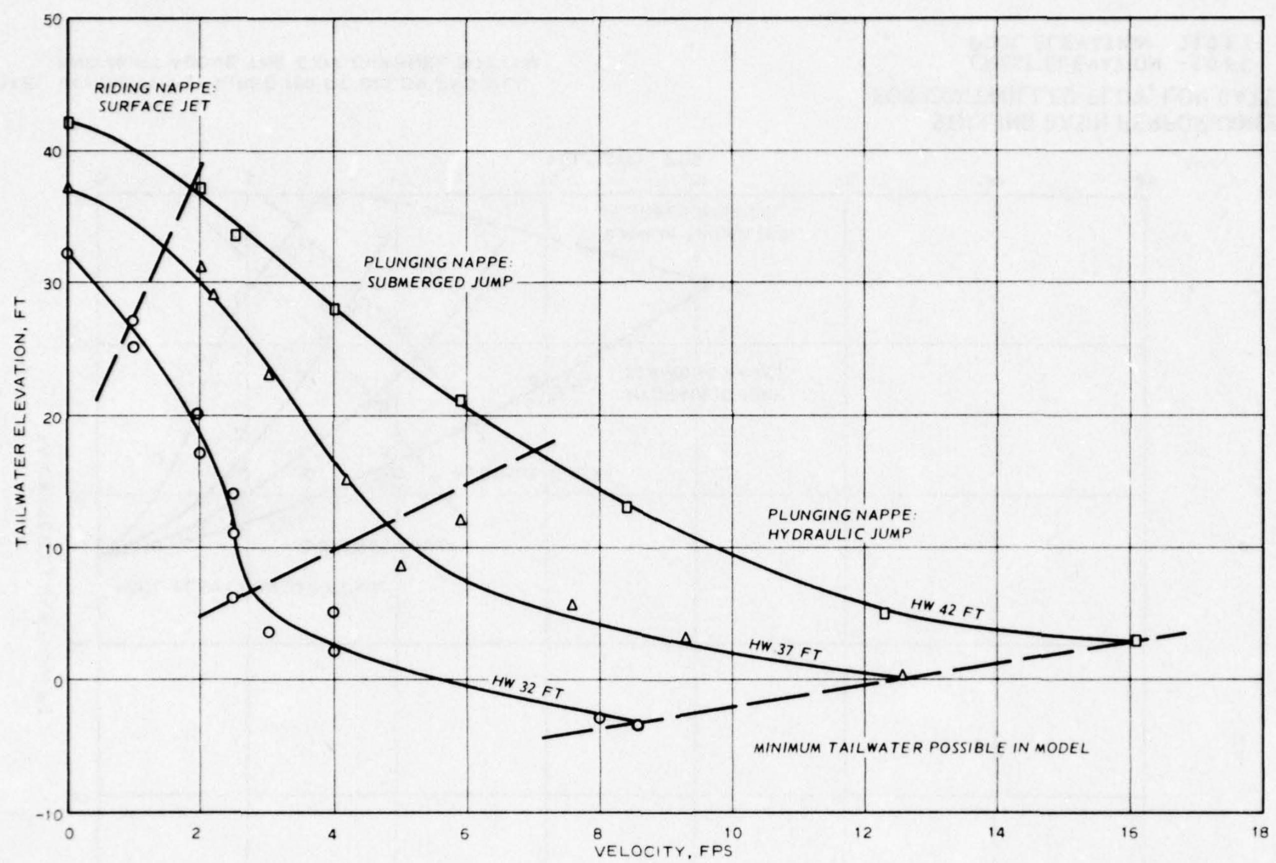
STILLING BASIN PERFORMANCE FOR UNCONTROLLED FLOW, HIGH GATE BAYS
CREST ELEVATION 10.0 FT



NOTE. GATE LEAF 4L IN LOW BAYS
VELOCITY MEASURED 100 FT BELOW END SILL
AND 10 FT ABOVE EXIT CHANNEL BOTTOM

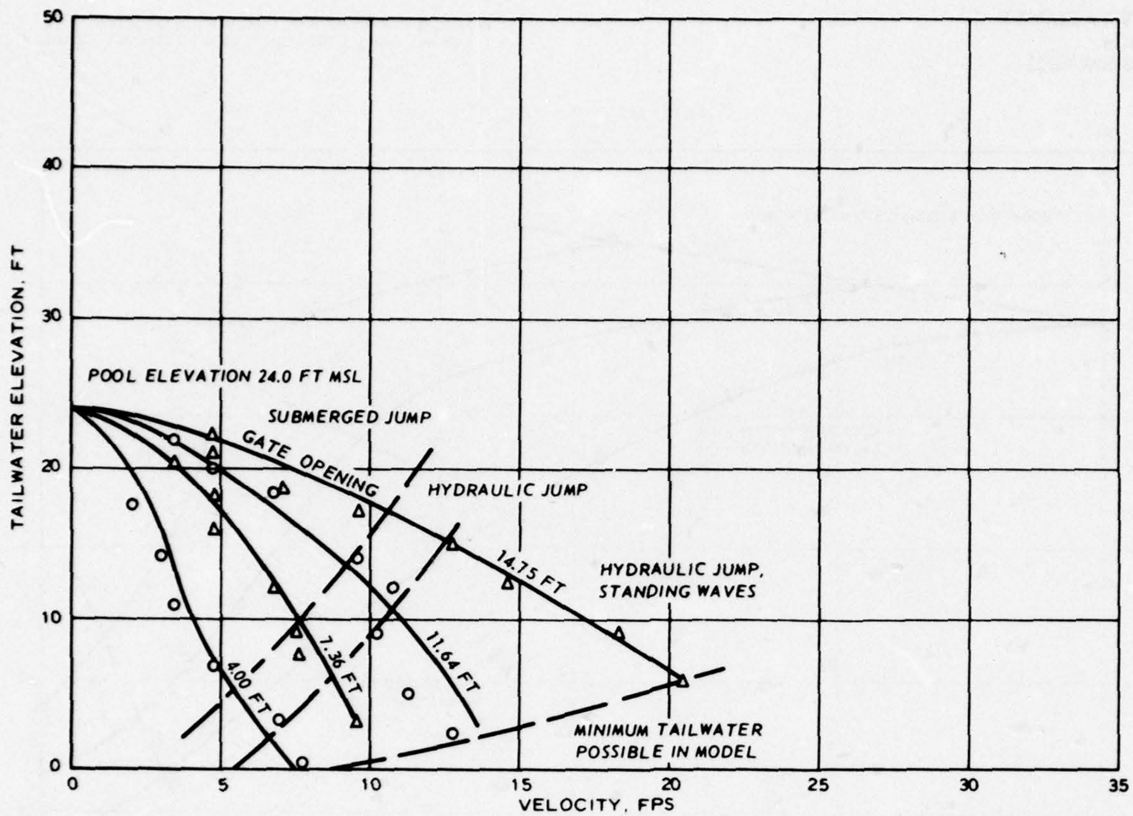
STILLING BASIN PERFORMANCE
FOR WEIR FLOW

WEIR ELEVATION 10.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE EXIT CHANNEL BOTTOM

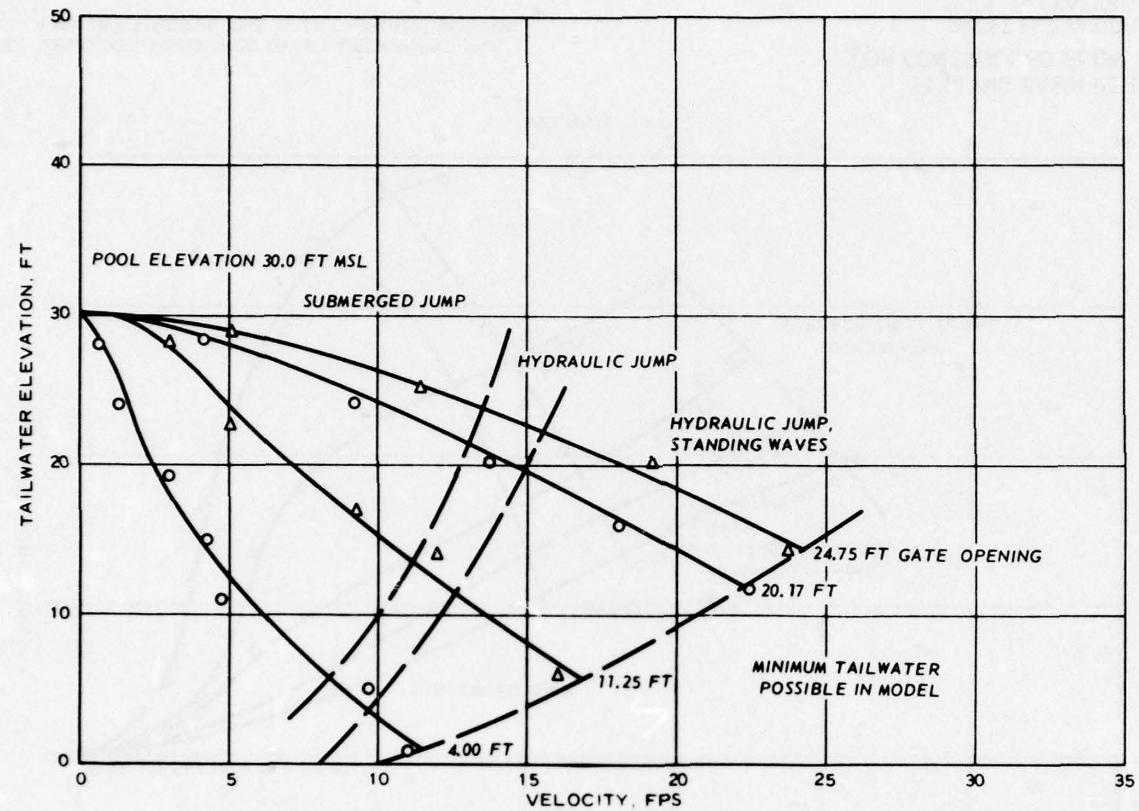
STILLING BASIN PERFORMANCE
FOR WEIR FLOW
LEAVES 4L & 3L IN LOW GATE BAYS
WEIR ELEVATION 29.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM

STILLING BASIN PERFORMANCE FOR CONTROLLED FLOW, LOW GATE BAYS

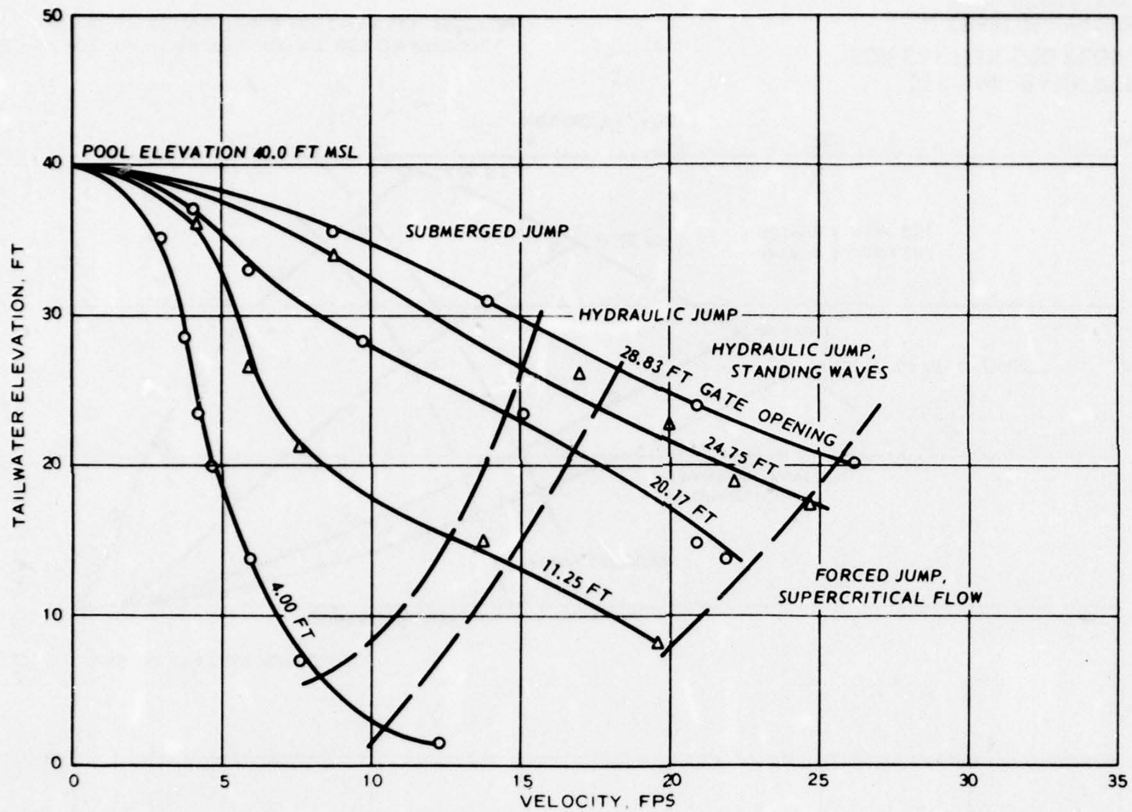
CREST ELEVATION -5.0 FT
POOL ELEVATION 24.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM

STILLING BASIN PERFORMANCE
FOR CONTROLLED FLOW, LOW GATE BAYS

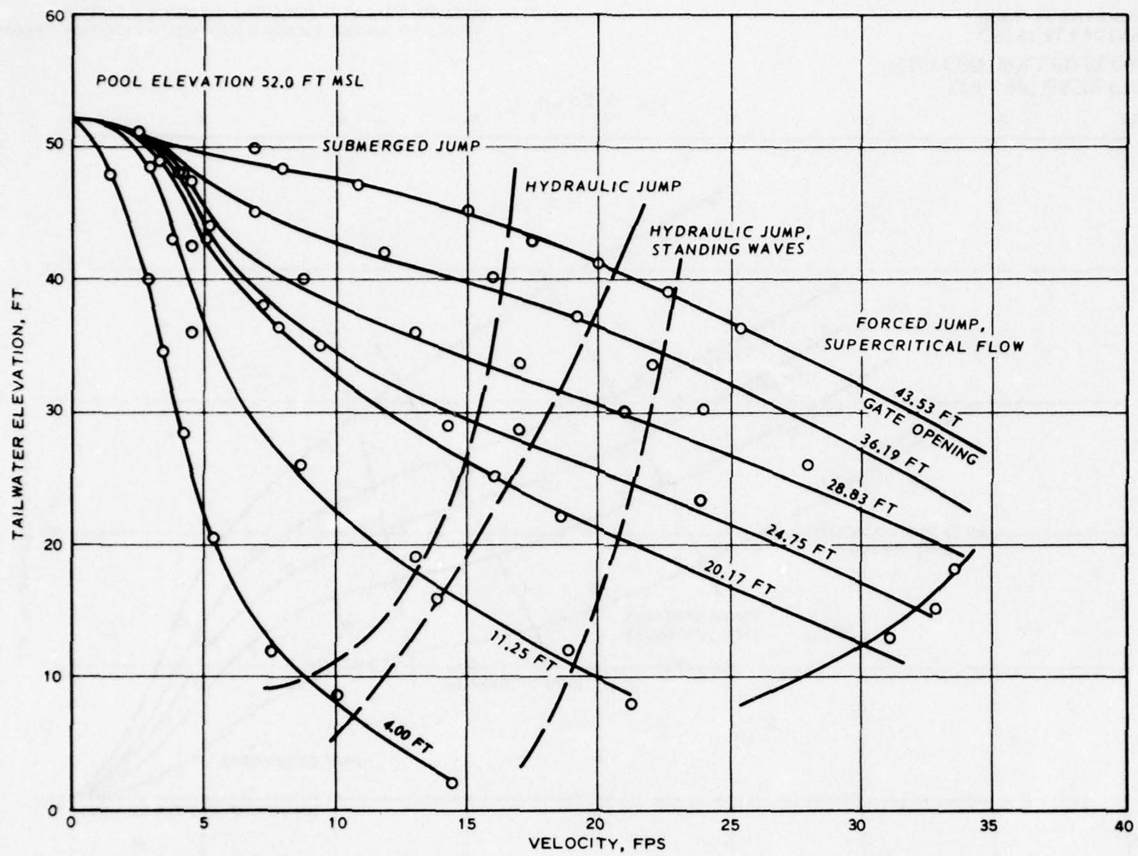
CREST ELEVATION -5.0 FT
POOL ELEVATION 30.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM

STILLING BASIN PERFORMANCE.
FOR CONTROLLED FLOW, LOW GATE BAYS

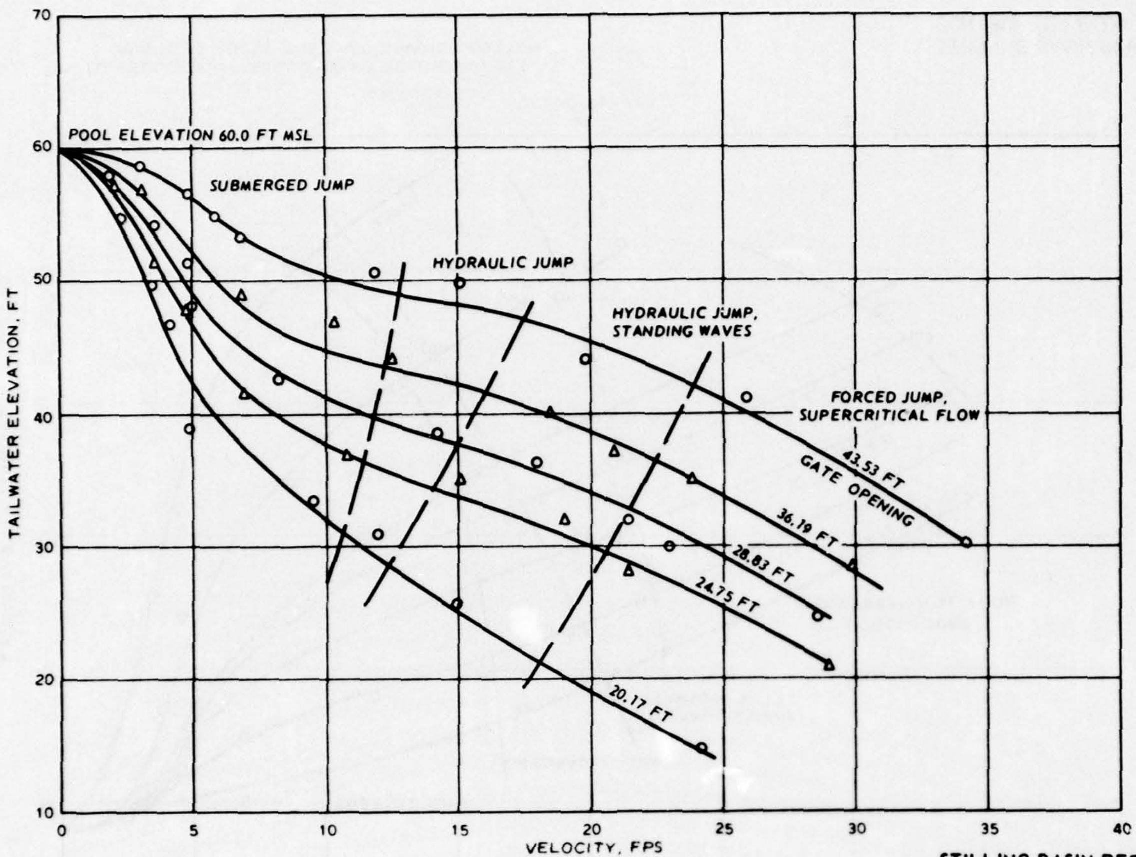
CREST ELEVATION -5.0 FT
POOL ELEVATION 40.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM

STILLING BASIN PERFORMANCE FOR CONTROLLED FLOW, LOW GATE BAYS

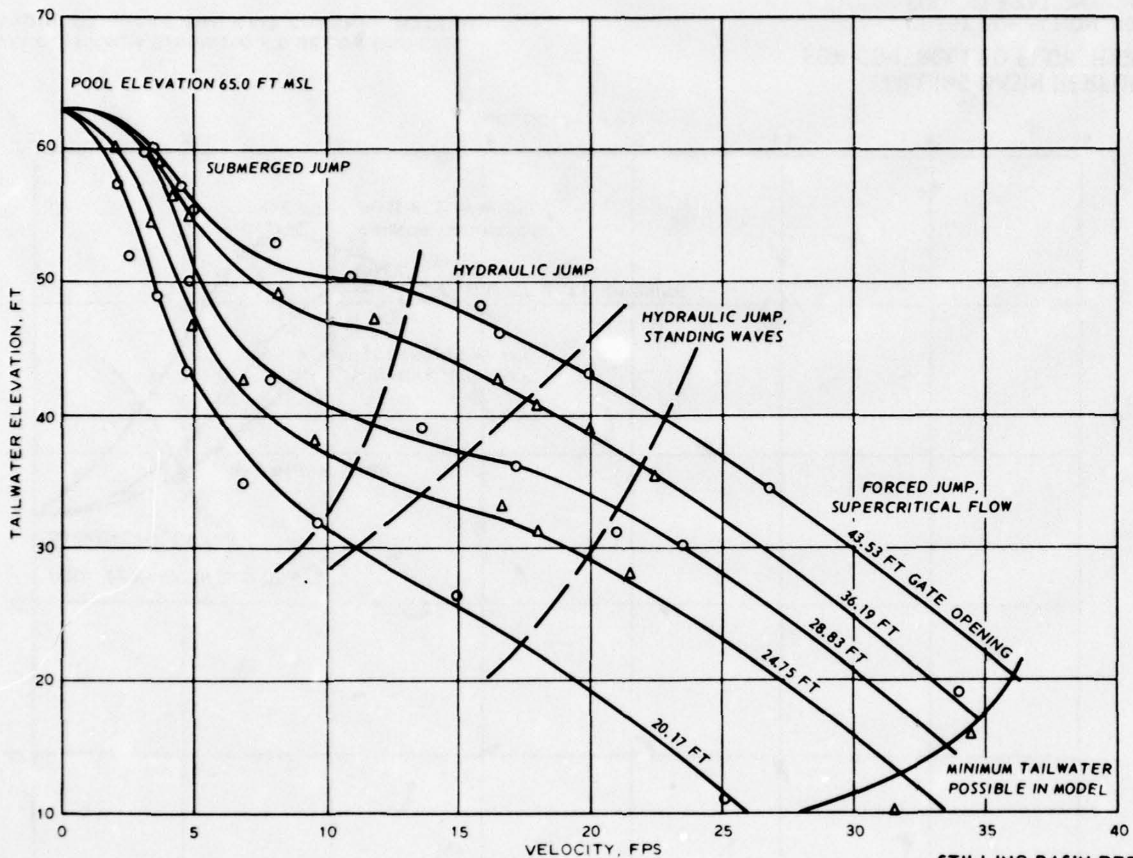
CREST ELEVATION -5.0 FT
POOL ELEVATION 52.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM.

STILLING BASIN PERFORMANCE FOR CONTROLLED FLOW, LOW GATE BAYS

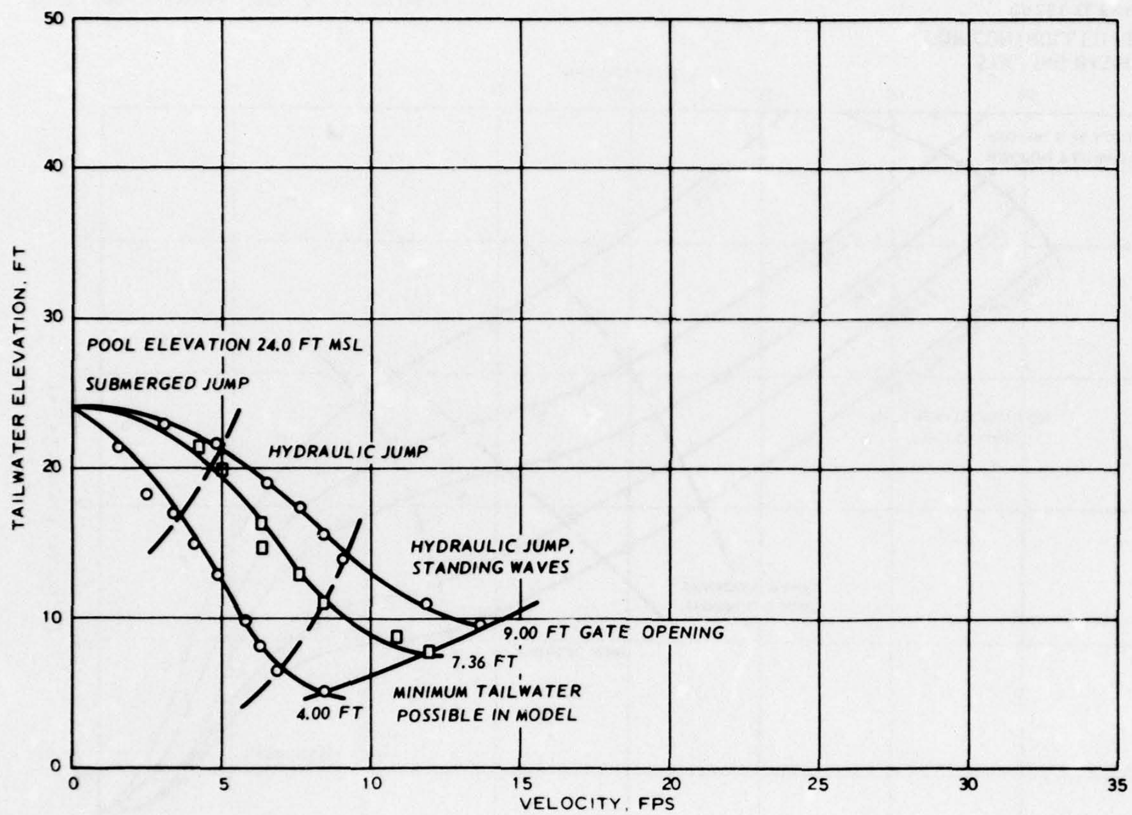
CREST ELEVATION -5.0 FT
POOL ELEVATION 60.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM.

STILLING BASIN PERFORMANCE FOR CONTROLLED FLOW, LOW GATE BAYS

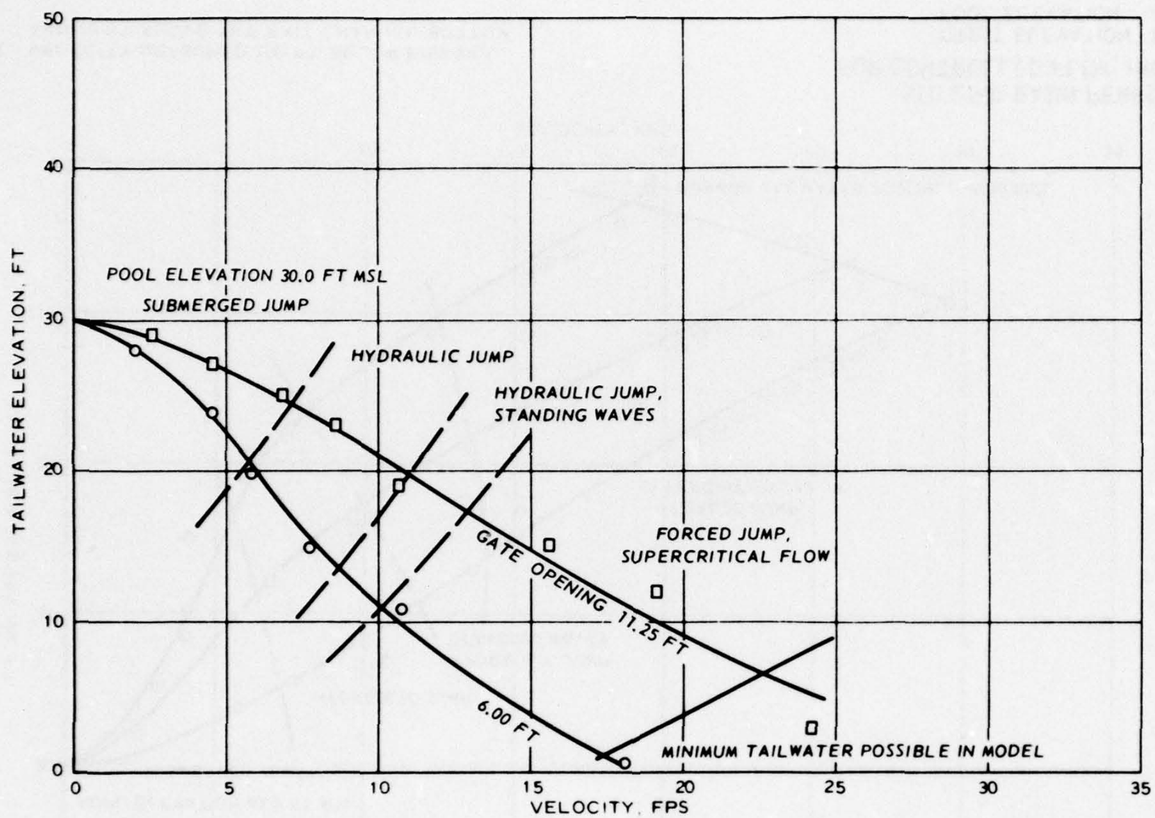
CREST ELEVATION -5.0 FT
POOL ELEVATION 65.0 FT



NOTE VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM

STILLING BASIN PERFORMANCE FOR CONTROLLED FLOW, HIGH GATE BAYS

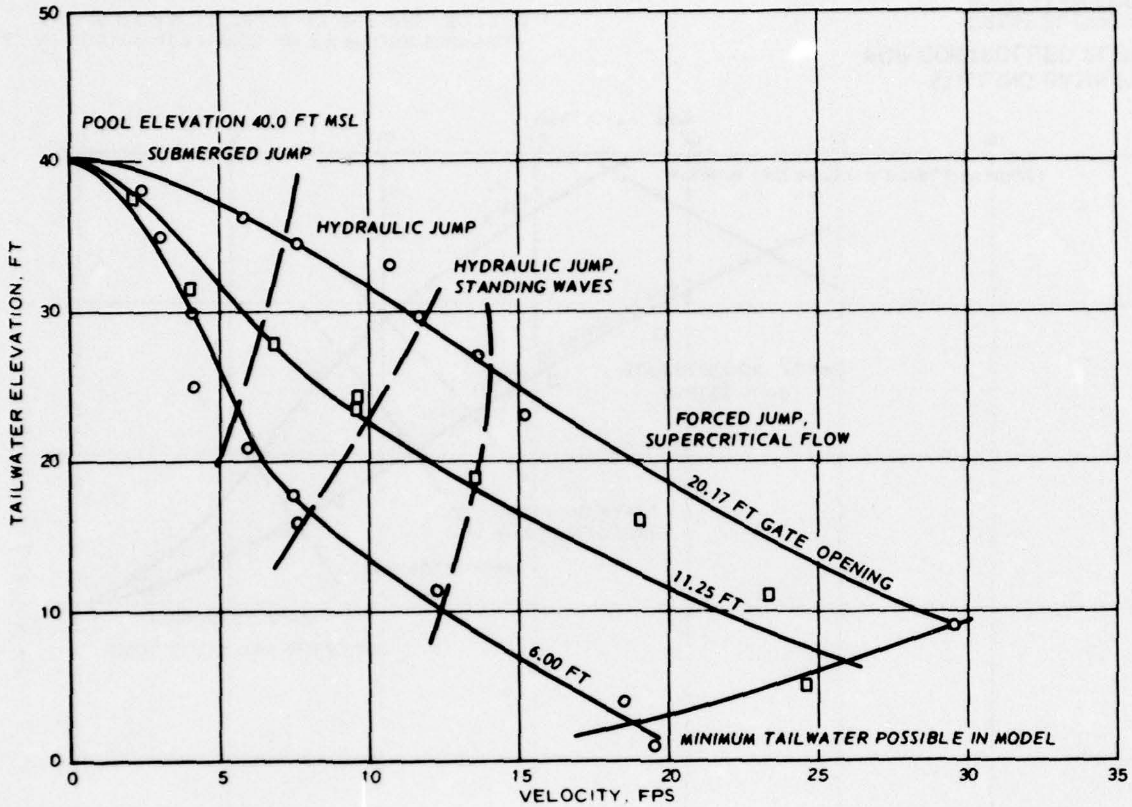
CREST ELEVATION 10.0 FT
POOL ELEVATION 24.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM

STILLING BASIN PERFORMANCE
FOR CONTROLLED FLOW, HIGH GATE BAYS

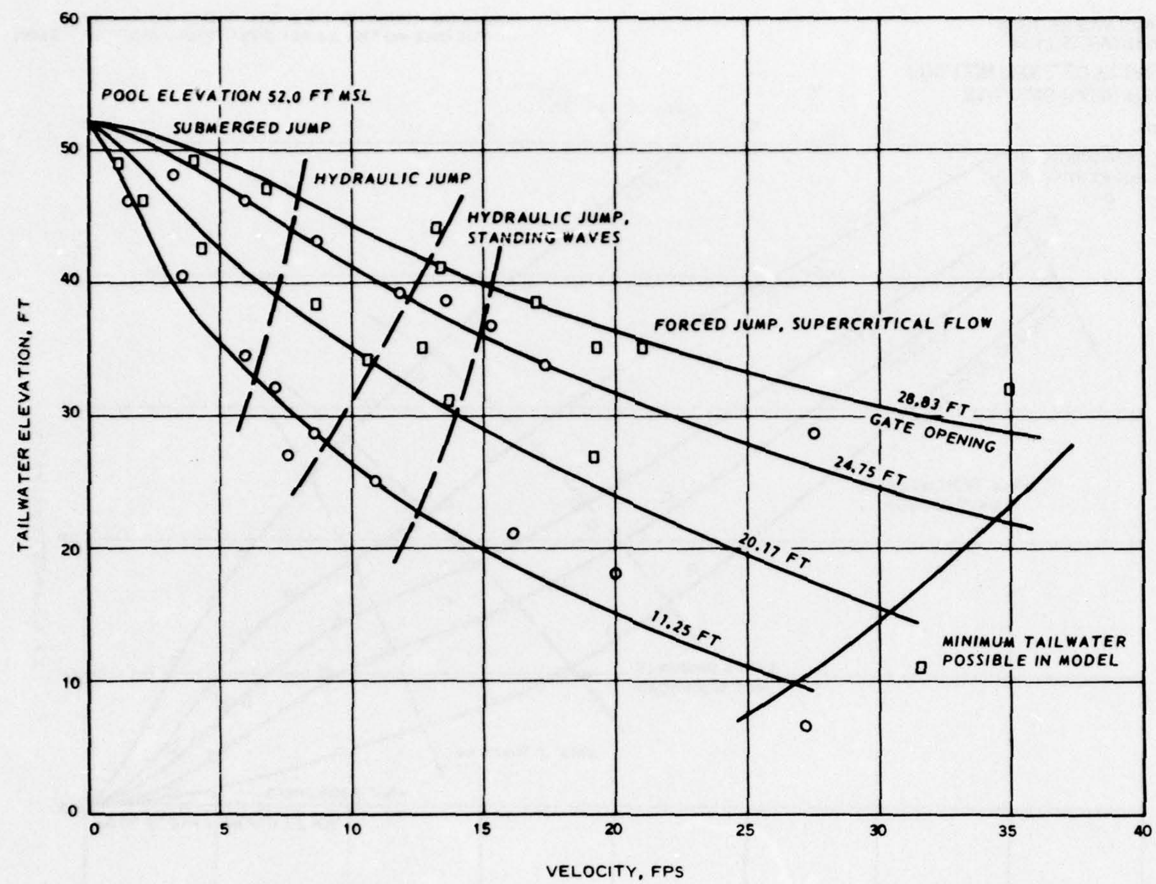
CREST ELEVATION 10.0 FT
POOL ELEVATION 30.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM

STILLING BASIN PERFORMANCE
FOR CONTROLLED FLOW, HIGH GATE BAYS

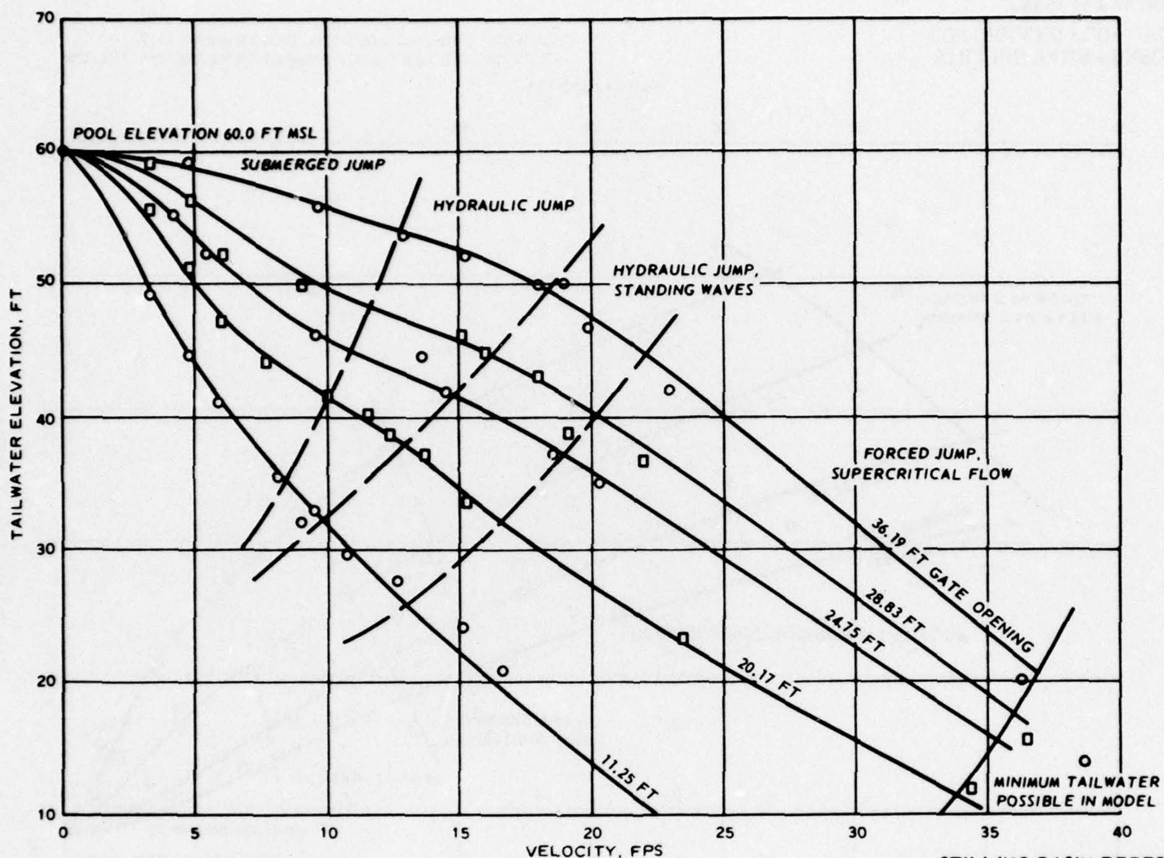
CREST ELEVATION 10.0 FT
POOL ELEVATION 40.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM

STILLING BASIN PERFORMANCE FOR CONTROLLED FLOW, HIGH GATE BAYS

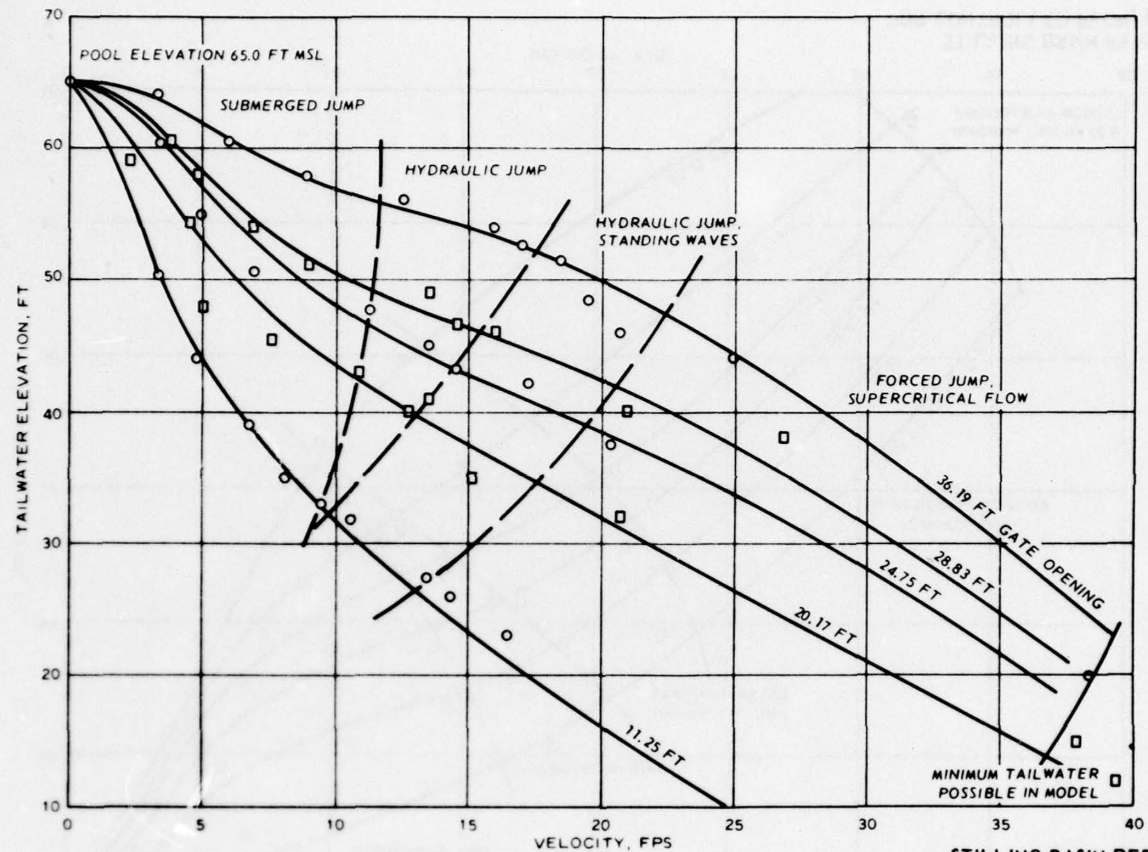
CREST ELEVATION 10.0 FT
POOL ELEVATION 52.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM.

STILLING BASIN PERFORMANCE FOR CONTROLLED FLOW, HIGH GATE BAYS

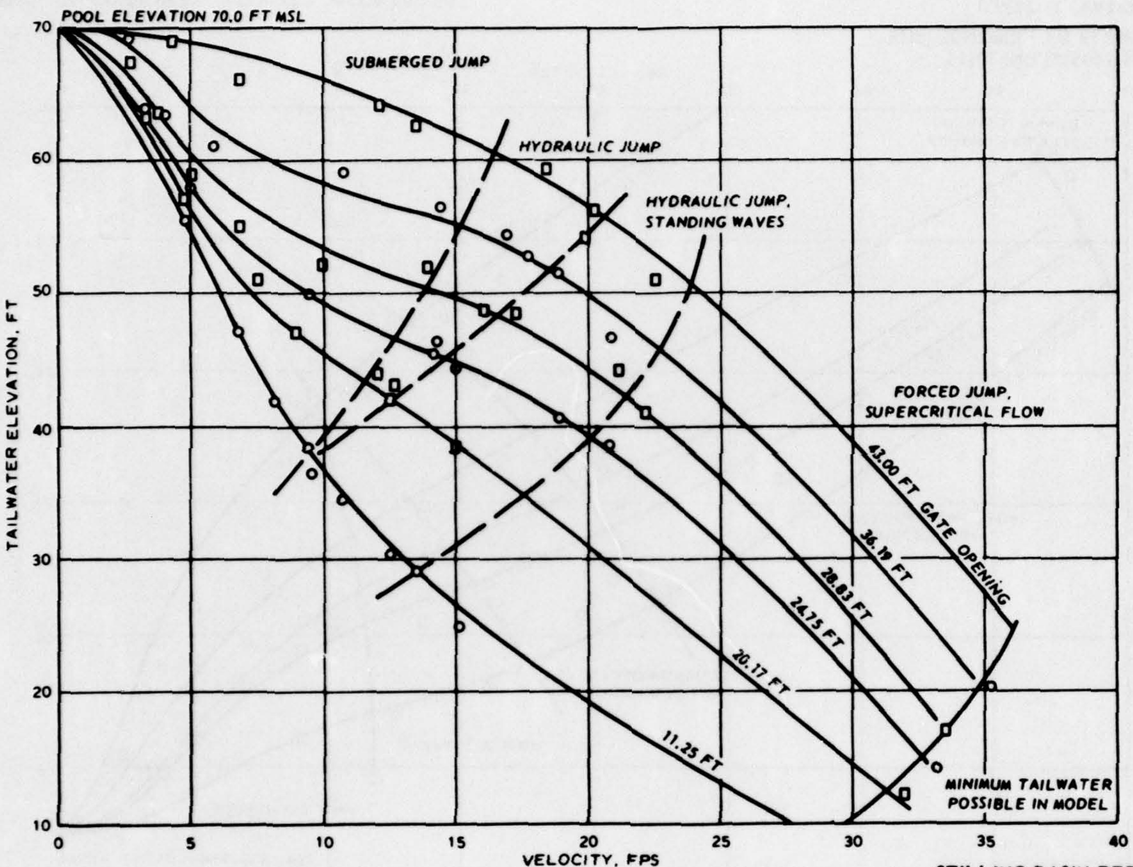
CREST ELEVATION 10.0 FT
POOL ELEVATION 60.0 FT



NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM.

STILLING BASIN PERFORMANCE FOR CONTROLLED FLOW, HIGH GATE BAYS

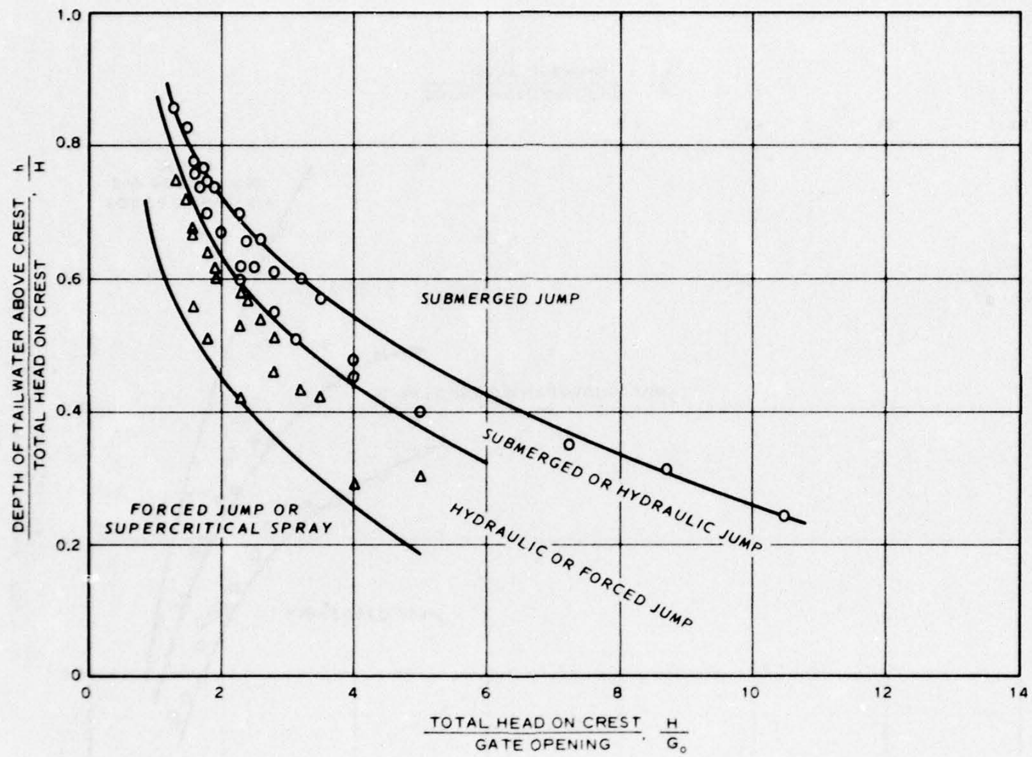
CREST ELEVATION 10.0 FT
POOL ELEVATION 65.0 FT



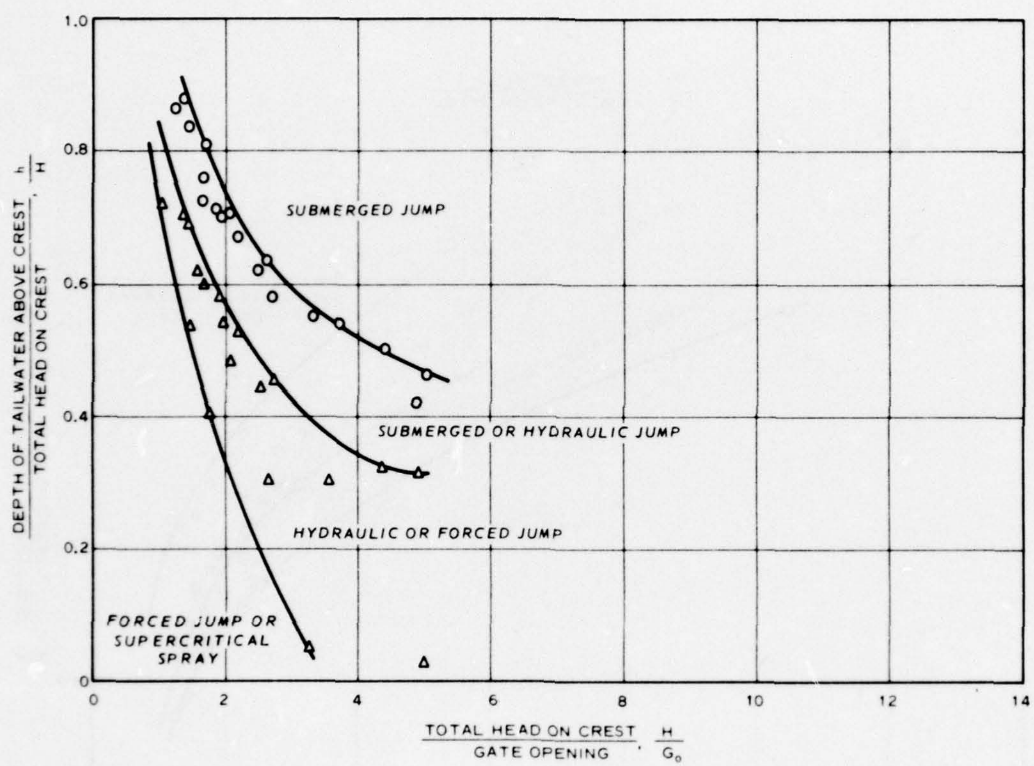
NOTE: VELOCITY MEASURED 100 FT BELOW END SILL AND 10 FT ABOVE THE EXIT CHANNEL BOTTOM.

STILLING BASIN PERFORMANCE FOR CONTROLLED FLOW, HIGH GATE BAYS

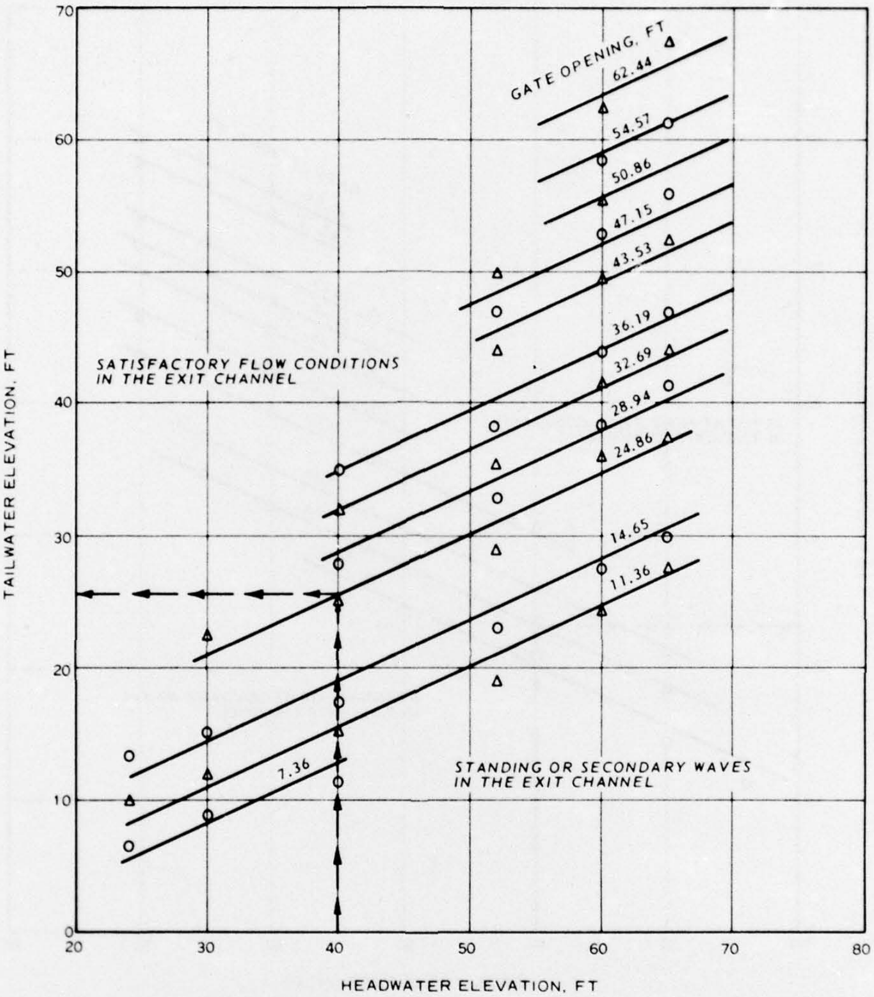
CREST ELEVATION 10.0 FT
POOL ELEVATION 70.0 FT



STILLING BASIN PERFORMANCE
FOR CONTROLLED FLOW
LOW GATE BAYS



STILLING BASIN PERFORMANCE
FOR CONTROLLED FLOW
HIGH GATE BAYS



EXAMPLE PROBLEM:

GIVEN: HW = 40.0, G_0 = 24.86, FIND THE MINIMUM TAILWATER FOR SATISFACTORY FLOW CONDITIONS IN THE EXIT CHANNEL.

SOLUTION: MINIMUM TAILWATER = 25.5

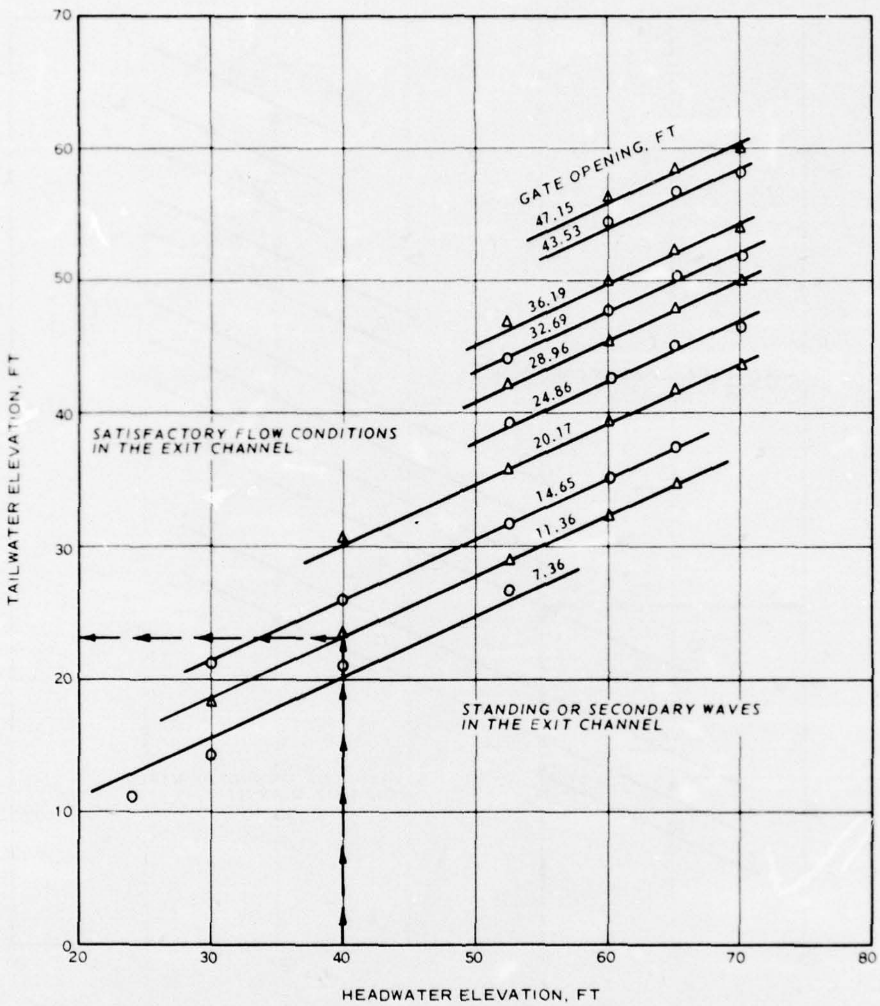
OR

GIVEN: HW = 40.0, TW = 25.5, FIND THE GATE OPENINGS ASSOCIATED WITH SATISFACTORY FLOW CONDITIONS IN THE EXIT CHANNEL.

SOLUTION: GATE OPENINGS OF 24.86, 14.65, 11.36 AND 7.36

REFERENCE PLATE 56

MINIMUM TAILWATER CURVES
LOW GATE BAYS



EXAMPLE PROBLEMS:

GIVEN: HW = 40.0, G_o = 11.36, FIND THE MINIMUM TAILWATER FOR SATISFACTORY FLOW CONDITIONS IN THE EXIT CHANNEL.

SOLUTION: MINIMUM TAILWATER = 23.0

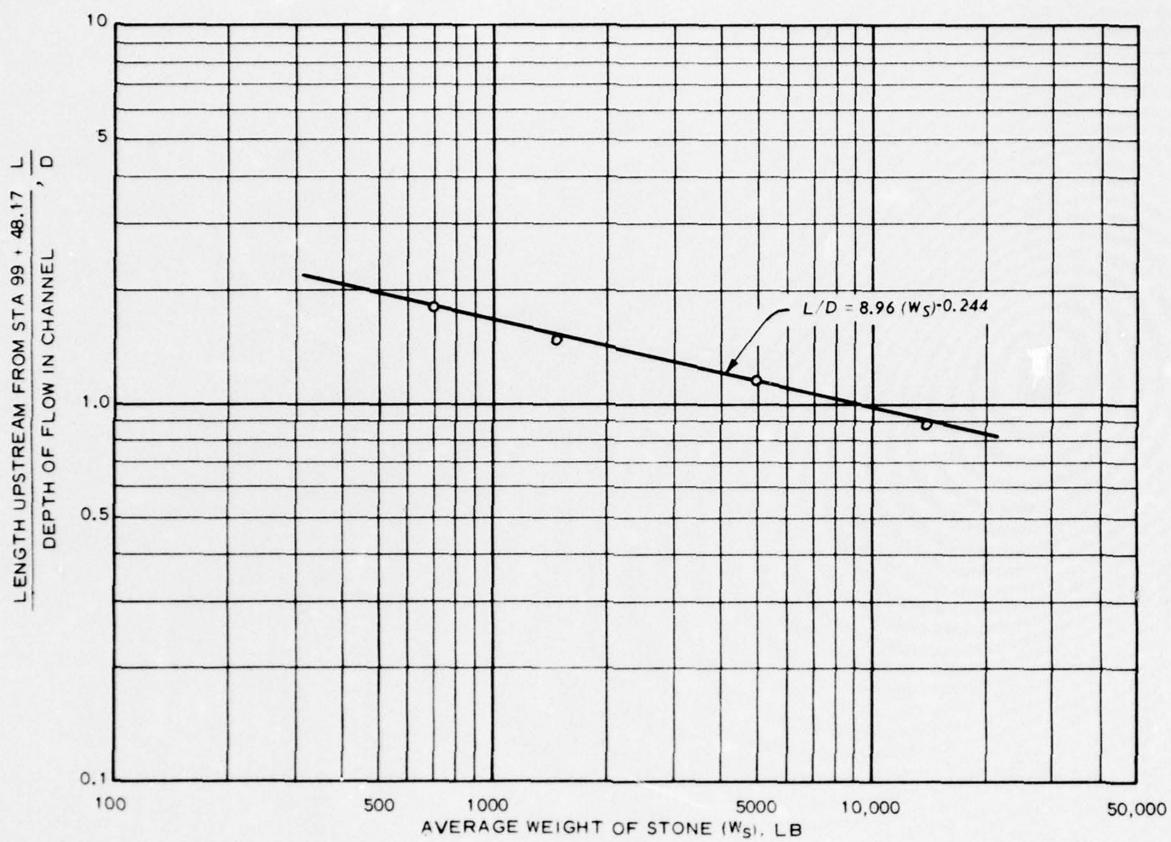
OR

GIVEN: HW = 40.0, TW = 23.0, FIND THE GATE OPENINGS ASSOCIATED WITH SATISFACTORY FLOW CONDITIONS IN THE EXIT CHANNEL.

SOLUTION: GATE OPENINGS OF 11.36 AND 7.36

REFERENCE PLATE 62

MINIMUM TAILWATER CURVES
HIGH GATE BAYS



NOTE: CURVE IS BASED ON ONE FLOW CONDITION, UNCONTROLLED FLOW THROUGH THE THREE LOWER GATE BAYS (CREST EL -5.0 FT). HEADWATER 49.5 FT, TAILWATER 46.0 FT, DEPTH IN APPROACH 54.5 FT.

PLACEMENT OF STONE

APPENDIX A: NOTATION

C	Discharge coefficient for free uncontrolled flow
C_g	Discharge coefficient for free controlled flow
C_{g_s}	Discharge coefficient for submerged controlled flow
C_s	Discharge coefficient for submerged uncontrolled flow
F_T	Total horizontal force acting on gate, kips
F_1	Static force on front of gate, kips
F_2	Velocity head on front of gate, kips
F_3	Static force on back of gate, kips
g	Acceleration due to gravity, ft/sec^2
G_o	Gate opening, ft
h	Tailwater elevation referred to weir crest, ft
H	Total head on weir (including velocity head), ft
H_g	Total head on gate ($H - G_o/2$), ft
L	Net length of spillway crest, ft
Q	Discharge per bay, cfs
ΔH	Difference between total energy flow in the approach channel and elevation of tailwater with reference to the spillway crest ($H - h$), ft

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Rothwell, Edward D
Old River existing low-sill control structure, Louisiana; hydraulic model investigation, by Edward D. Rothwell [and] John L. Grace, Jr. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977.
1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Technical report H-77-2)
Prepared for U. S. Army Engineer District, New Orleans, New Orleans, Louisiana.

1. Control structures. 2. Hydraulic models. 3. Old River Control Structure. 4. Open channel flow. 5. Stilling basin performance. I. Grace, John Linson, joint author. II. U. S. Army Engineer District, New Orleans. (Series: U. S. Waterways Experiment Station. Technical report H-77-2)
TA7.W34 no.H-77-2